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The Institute of Vitreous Enamellers
The National Ironfounding Employers' Federation
The Welsh Engineers' and Founders' Association
and
The Foundry Trades' Equipment and Supplies Association

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The Chemical Engineering Congress—2

Before surveying two Papers of interest to founders in group B of the Chemical Engineering Congress, we may mention the Dutch Paper in group A on the corrosion and protection of cast iron and steel pipe lines in the soil. A lengthy Paper in Group B from U.S.A. was that of Mr. J. A. Lee on metals and alloys used in the construction of chemical plant. This naturally covers the chromium and chromium-nickel steels. In 1926 chromium steels were first used as castings in the States in plant used for the production of nitric acid by the oxidation of ammonia. The applications of nickel and copper are given and particularly those of the nickel-copper alloys, of which Monel Metal is the most important. These show good resistance to corrosion by acids, except those of a highly oxidising character. For chlorine and hydrochloric acid plants mention is made of an alloy of 58 per cent. nickel, 20 per cent. molybdenum and 20 per cent. iron, containing in the cast form chromium and tungsten also. The Paper deals with the other non-ferrous metals, principally in the wrought form.

A Paper by Mr. E. Norlin gives Swedish experience with non-corrodible materials in the chemical industry. It is pointed out that ordinary ferrous materials are not as a rule very resistant to corrosion, being resistant only to alkalis or to oxidising agents like concentrated nitric acid that make the iron surface passive. For such uses cast iron is more resistant to corrosion than the other iron-carbon alloys, especially if the casting skin is not removed. For coating processes, lead can be applied by direct dipping in molten lead preceded by galvanising, or by spraying. Enamelled iron vessels possess important advantages because their mechanical strength is equal to that of iron, whereas their resistance to corrosion compares with that of porcelain. On the other hand they are very sensitive to rapid variations in temperature on account of the difference in the coefficient of expansion of enamel and of iron, and a further drawback of enamel is its brittleness. Rubber coatings on iron appear to have reached a high state of development. In the manufacture of wood pulp, it is said that cast iron and wrought iron are comparatively sensitive to corrosion, but so far it has been impossible to replace them by any other sufficiently resistant and cheap ferrous alloy. Confirmation is given of the resistance to sulphur atmospheres offered by high-chromium alloys. Altogether, the development of special alloys for chemical engineering has reached a high pitch in various countries, and metallurgical research institutions in this country should bear this fact in mind.

Birth Marks

It is a modern necessity that all castings should carry indication of their history, but at the same time there is no need for them to bear a mass of figures like the internal reference number of a letter from a Government department. A casting could carry the following information:—Trade mark of the manufacturing company; the grade of metal used (high-duty, alloyed or easily machinable); the date it was made; the number of the heat of metal used to cast it; the identification of the moulder who constructed the mould; the pattern number, and perhaps a special identification number of its own. Obviously no casting need carry seven "characters," but in diverse cases all of them should be used. Where a foundry is making for the trade in repetition lines, then a trade mark, a cast number and the moulder's mark should suffice. Where castings are to be machined in the manufacturer's works, then an indication should be given of the type of metal used so that the machine-shop foreman will have some knowledge of the machining speeds to use. The mark of the moulder and, sometimes, the pattern number can be usefully included. For such important jobs as rolls and ingot moulds, a serial number should be sufficient, provided the technical history of the job is properly recorded. It will usually be preferable to give the number of the month rather than the actual date, but at the end of each year a different fount of type might well be used. Again, the year can be identified by putting the moulder's (or shift) indication before or after the month.

The insertion of the pattern number can also be extremely useful where two patterns strongly resemble each other dimensionally; this imprint may obviate rejects through machining errors. The moulder's imprint is useful in cases where piece work and bonus systems obtain. The use of a trade mark is obvious to founders who are proud of their productions, as it serves as an advertisement for their wares and gives confidence to the buyers. The whole object of placing identification marks on castings is to obtain a maximum of information by the use of as few marks as possible. To attempt to do too much is to court failure, as the moulder's job is to mould and wherever possible the lettering and numbering should be done by the pattern shop.

(*Concluded on page* 20.)

The Institute of Metals

ANNUAL AUTUMN MEETING IN PARIS

As previously announced, the twenty-eighth Annual Autumn Meeting of the Institute of Metals will be held in Paris from September 14 to 18, by the kind invitation of the Bureau International des Applications de l'Aluminium, with the cordial co-operation of the Chambre Syndicale des Métaux à Paris. The headquarters of the Institute, and the office of the honorary local secretary, will be in the Maison de la Chimie, 28 rue St. Dominique, Paris 7e, where all the meetings will be held. An influential Reception Committee (of which the honorary secretary is Mr. J. S. Douchement) has been formed to carry out the necessary arrangements, which are outlined in the programme given below.

Programme

MONDAY, SEPTEMBER 14.

10 a.m. to noon, and 2 p.m. to 7 p.m.—The office of the honorary local secretary will be open at the Maison de la Chimie, 28 rue St. Dominique, Paris, 7e, for the issue of tickets, badges, etc., and for general information.

7.45 for 8 p.m.—Fifteenth Autumn Lecture on "The Scientific Organisation of Factories," by Professor P. A. J. Chevenard (Corresponding Member to the Council for France), in the Grande Salle of the Maison de la Chimie.

9 p.m. to 10 p.m.—Informal gathering of members; light refreshments will be provided.

10 p.m. to 11.30 p.m.—Display of cinematograph films of metallurgical interest in the Grande Salle of the Maison de la Chimie.

TUESDAY, SEPTEMBER 15.

9.45 a.m.—An official welcome will be extended to members and their ladies in the Amphitheatre of the Maison de la Chimie.

10 a.m. to 12.30 p.m. — General meeting of members.—In accordance with the Rules, there will be presented a list of members nominated for election to the Council. Papers will be presented for discussion in accordance with the list given below.

Ladies. Morning free or available for visit to the new Halls of the Musée du Louvre, starting from the Maison de la Chimie.

1 p.m.—Members and their ladies who so desire may partake of luncheon in the neighbouring Hotel Palais d'Orsay (tickets 4s. each, exclusive of wine).

2 p.m. — Members will leave Hotel Palais d'Orsay for the following visits:—

(*a*) Renault Motor Works, Billancourt. (Number unlimited.)

(*b*) Tréfileries de Vitry (Compagnie Generale d'Electrométallurgie) and Cableries de St. Maurice (Tréfileries & Laminoirs du Havre). The works are concerned particularly with the rolling and drawing of copper. (Limited to 30 persons.)

(*c*) Société des Phares Marchal à Pantin (Electrodeposition of nickel and cadmium), and the Works of the Société Française des Métaux et Alliages Blancs (White metals). (Limited to 30 persons); or to Société des Alliages d'Etain et Dérivés à Montreuil s/Bois (Tin alloys). (Limited to 30 persons.)

Ladies will leave the Hotel Palais d'Orsay for:—

(*d*) Visit to the Usines Heudebert (Food products) at Nanterre. (Limited to 60 persons.) Tea will be served at the conclusion of the visit.

(*e*) The Works of the Société Pierrot Gourmand à Ivry. (Manufacturers of confectionery.)

8 p.m.—Banquet given by the Bureau International des Applications de l'Aluminium at the Maison de la Chimie. (Evening dress.)

WEDNESDAY, SEPTEMBER 16.

10 a.m.—General meeting of members in the Amphitheatre of the Maison de la Chimie. Papers will be presented for discussion in accordance with the list given below.

10 a.m.—*Ladies.* Morning free or available for visit to Notre-Dame and the Sainte-Chapelle, starting from the Maison de la Chimie.

1 p.m.—Members and their ladies who so desire may partake of luncheon in the neighbouring Hotel Palais d'Orsay (tickets 4s. each, exclusive of wine).

2 p.m.—Members will leave the Hotel Palais d'Orsay for the following visits:—

(*f*) Etablissements Lioré Olivier à Argenteuil (Aviation Works). (Limited to 50 persons.)

(*g*) Fonderie de Précision à Nanterre (Pressure castings of alloys of zinc and aluminium). (Limited to 30 persons.)

(*h*) Imprimerie de l'Illustration à Bobigny (Printing Works). Open to both Members and Ladies. (Number unlimited.)

Ladies will leave the Hotel Palais d'Orsay for a visit to the Château de Malmaison and Gardens of Bagatelle. (Limited to 40 persons.)

5.30 p.m.—Civic Reception at the Hotel de Ville by the Municipal Council of Paris. Cars will convey members from the Works and Gardens directly to the Hotel de Ville to arrive there at 5.15 p.m.

9 p.m.—Dance at the Pré Catelan, Bois de Boulogne. (Dress optional.)

THURSDAY, SEPTEMBER 17.

10 a.m.—Motors will leave the Hotel Palais d'Orsay for an all-day excursion to Versailles. Visit to the Château, lunch, visit to the Gardens and Trianons, followed by tea, returning about 6 p.m. The charge of the excursion, inclusive of lunch (with wine) and tea, 15s. per person.

FRIDAY, SEPTEMBER 18.

8.20 a.m.—Excursion to Rouen and visit to T.L.H. Works at Havre. The charge for the excursion, inclusive of meals, will be £1 14s. (Rouen), or £1 17s. (Havre).

Papers

The following Papers are expected to be submitted for discussion. The list is provisional:—

On September 15:

"The Conductivity of Super Purity Aluminium. The Influence of Small Metallic Additions," by G. G. G. Gauthier.

"The Complex Interdependence of the Properties of Alloys and the Industrial Conditions of Their Manufacture, Testing and Use," by R. de Fleury and H. Portier.

"Mechanical Properties of Aluminium and Its Alloys after Prolonged Heating," by Professor A. von Zeerleder and Dr. R. Irmann.

"An Anodic Treatment for the Production of Aluminium Reflectors," by N. D. Pullen.

On September 16:

"Mechanism of the Forgeability of various Light and Ultra-Light Alloys," by Professor A. M. Portevin and P. G. Bastien, D.Sc.

"Metals of the Platinum Group: Ores, Recovery and Refining, Fabrication and Uses, Properties," by R. H. Atkinson, M.A., and A. R. Raper, M.A.

"The Creep of Tin and Tin Alloys. Part I," by Professor D. Hanson, D.Sc., and E. J. Sandford, B.Sc.

"Veining and Sub-Boundary Structures in Metals," by L. Northcott, Ph.D.

"A Note on the Influence of Salt-Bath Heat-Treatment on the Corrosion-Resistance of Duralumin Sheet," by A. J. Sidery and B. Evans, B.Sc.

Professor ALBERT M. PORTEVIN

PROFESSOR PORTEVIN, the distinguished French metallurgist, was elected as an Honorary Member of the Institute of British Foundrymen at the Annual Conference in Glasgow last month. He is Professor at the Foundry High School in Paris and at the School of Arts and Manufactures. He is joint author, with Dr. Paul G. Bastien, of the French Exchange Paper which was presented at the Glasgow Conference and which is published elsewhere in this issue.

Birth Marks

(*Concluded from page* 19.)

For instance, the type of metal to be used; the pattern number, and the trade mark (where these be necessary) should be attached to the pattern, leaving merely the shift or moulder's imprint and the date identification to be inserted, preferably in a prepared recess in the pattern. Except in jobbing foundries making large castings it is extremely difficult to imprint on a casting the number of the cast.

It will thus be seen that, intelligently carried out, birth marking can serve a number of extremely useful purposes in the life of a casting, and even at its death, that is when it reaches the cupola stage, it may prevent a useless waste of the special alloys the casting may contain.

Scottish Conference Fund

The sum of £70 11s. 8d. was contributed by the Foundry Trades' Equipment and Supplies Association to the fund for the recent Scottish Conference of the Institute of British Foundrymen.

The members of the Association who contributed were:—The Atlas Preservative Company, Limited; Bradley & Foster, Limited; Coleman Foundry Equipment Company, Limited; Constructional Engineering Company, Limited; Wm. Cumming & Company, Limited; Fordath Engineering Company, Limited; Foundry Plant & Machinery, Limited; THE FOUNDRY TRADE JOURNAL; General Refractories, Limited; Paterson Hughes Engineering Company, Limited; Spermolin, Limited; Sterling Foundry Specialties, Limited; and Thomas Wilkinson & Company, Limited.

Welsh Engineers' Wages Award

The Welsh Engineers' and Founders' Joint Board last week considered the men's demand for increased wages. It was decided to give an increase of 2s. 6d. per week to adult engineers and 5 per cent. on weekly wages to all employees under 21 years of age. The increases take effect as from Monday.

The Influence of Wall-Thickness on the Mechanical Properties of Cast Iron*

By H. JUNGBLUTH, Essen

[GERMAN EXCHANGE PAPER.]

I.—Historical

The fact that grey castings have different strength properties according to their thickness is well-known. In addition to *C. v. Bach*† who as early as 1888 studied the mechanical strength of castings of different sectional thickness. W. J. Keep[1] in 1906 drew the general conclusion from a series of investigations that the strength of a casting of given sectional thickness could not be derived by a mathematical formula from the mechanical values obtained for test bars of other dimensions. Although Keep did not arrive at a solution for this problem, he nevertheless clearly formulated the practical aspects of the question. The practical foundryman is concerned with two questions: firstly, what is the strength of a casting at different sectional thicknesses, and secondly, what relation exists between the strength properties in sections of different thickness of a casting and those of a test bar cast either separately or integrally with a casting and which the foundryman uses for his own tests? During subsequent years various investigators studied this problem, the impetus for this work being provided mainly by British and American research workers.

In the first instance numerical data alone were collected and no attempt was made to derive from these experiments any general laws which, if possible, could be formulated quantitatively. Of the few workers who did indeed make some advance in this direction, passing reference should be made to *W. H. Rother and V. M. Mazurie*[20] who proposed the casting and testing of several bars of different wall thickness instead of only a single one, and to *J. W. Bolton*[21] who suggested giving the test bars the same ratio of surface to volume as that of the castings. Later *M. v. Schwarz and A. Väth*[46] followed up this suggestion and showed that under certain conditions satisfactory agreement between the strength of a casting as a whole and that of a test bar can be obtained if the diameter of the bar is made twice the wall thickness under test.

Subsequently research followed three main directions. On the one hand, as the problem as a whole proved to be too complex, one group of investigators devoted its attention to a partial aspect and attempted to find the quantitative relations existing between test bars of different diameters and different compositions. This was indeed the first part of Keep's[1] formulation of the whole problem. *G. Meyersberg*[22] in 1931 published certain equations which represented the quantitative relationship over a certain range between the diameter of the test bar and the mechanical property in question. But as, however, *F. B. Coyle*[23] had already shown in 1929 that a logarithmic relation existed between the mechanical strength and the test-bar diameter, *H. Jungbluth and P. A. Heller*[39] and *P. A. Heller and H. Jungbluth*[40] employed this observation in order to arrive at a numerical value for the "sectional sensitivity" in terms of the tangent of the slope of the logarithmic line of reference. They succeeded in obtaining a definite relationship between the "sectional sensitivity" on the one hand and the Maurer diagram* and the quality of grey iron respectively on the other. This part of the problem was thus solved at that time. On the other hand E. Dübi[49 51] tried to clarify the relationship between the strength of the test bar and that of the casting by introducing the concept of a "hardness characteristic curve" ("Härtecharakteristik"), commencing from the assumption that there exists a connection between the strength and the Brinell hardness, at least within a limited range. His purview was therefore the second part of Keep's question.

Finally, the third group of investigators, especially the school of *E. Piwowarsky*[37 43 45 50 52] attempted to deal with the influence of alloy components not normally present in cast iron on sectional sensitivity. These workers adopted as a fundamental measure the exponent "a" introduced by *H. Jungbluth and P. A. Heller*[39 40], i.e., the tangent of the slope of the logarithmic line of reference. This is in general outline the progress of the subject under review up to the present day. The problem is, however, not yet finally solved. An exact scientific formulation of the problem is given below.

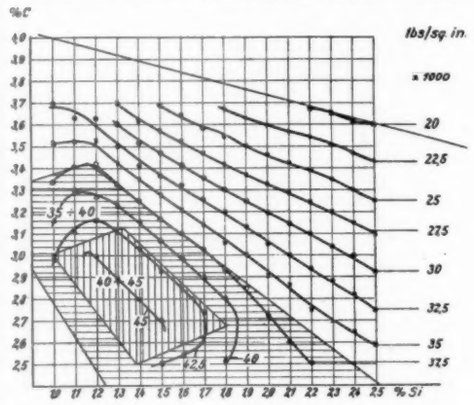

FIG. 1.—RELATIONSHIP BETWEEN C AND Si AND CONSTANT *c*, ACCORDING TO COYLE'S FORMULA.

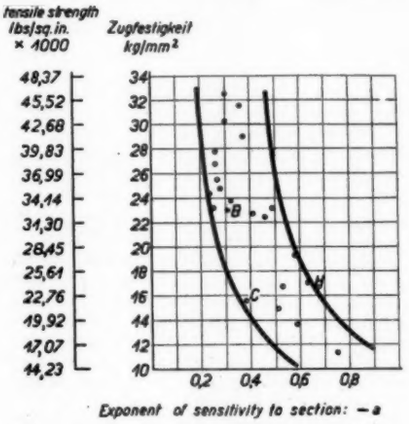

FIG. 2.—RELATIONSHIP BETWEEN TENSILE STRENGTH AND SECTIONAL SENSITIVITY.

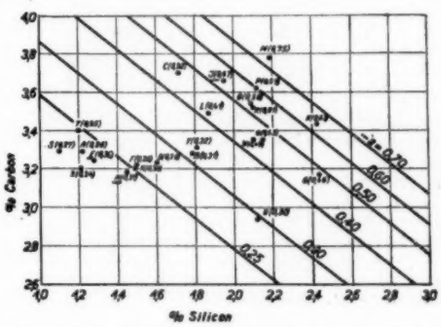

FIG. 3.—DIAGRAM OF SECTIONAL SENSITIVITY.

II.—Sectional Sensitivity

(a) Test Bars

The question of the pure sectional sensitivity will be discussed first. The quantitative laws governing sectional sensitivity are based on the conclusion stated by F. B. Coyle[23] that the diminution in the tensile strength of test bars of different thicknesses plotted in a system of co-ordinates with logarithmic axes is represented by a straight line. The relationship between the diameter of the test bar and its strength can therefore be expressed by an equation of the form:

$$y = c \cdot x^m$$

where

c is a constant,
x the diameter of the test bar and
m an exponent.

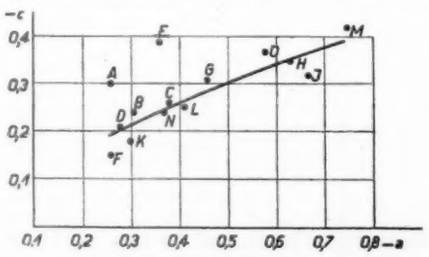

FIG. 4.—RELATIONSHIP BETWEEN EXPONENTS *a* (TENSILE STRENGTH) AND *c* (BRINELL HARDNESS), ACCORDING TO HELLER AND JUNGBLUTH.

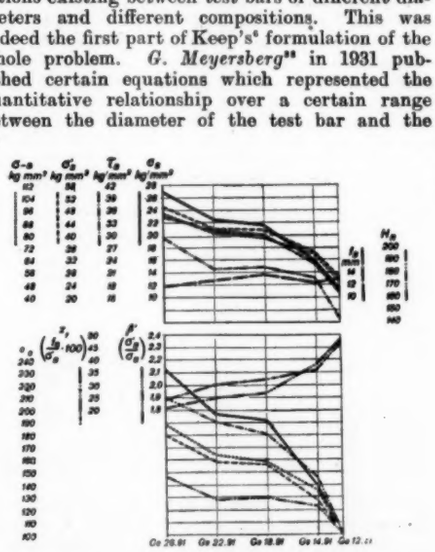

FIG. 5.—RELATIONSHIP BETWEEN MECHANICAL PROPERTIES OF STANDARD GRADES OF CAST IRON.

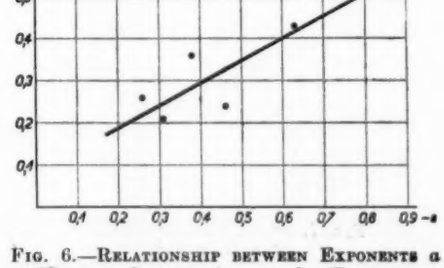

FIG. 6.—RELATIONSHIP BETWEEN EXPONENTS *a* (TENSILE STRENGTH) AND *b* (TRANSVERSE STRENGTH), ACCORDING TO HELLER AND JUNGBLUTH.

* Paper presented at the Annual Conference of the Institute of British Foundrymen in Glasgow last month.

† The Bibliography appears at the end of this Paper.

* "a. Kruppsche Mitteilungen," 5 (1924), pp. 115–22; "Stahl u. Eisen," 44 (1924), pp. 1522–24.

Expressing this equation logarithmically, viz., $\log y = m \log x + \log c$ shows that m stands for the slope of the straight line plotted in logarithmic co-ordinates, and c for the strength of the test bar with the diameter 1 (for Coyle's case 1). From his curves Coyle deduced that $m = -\frac{1}{2.02}$. The different grades of cast iron differ according to Coyle only in regard to the constant c; his Table II gives different values of c in relation to the carbon and silicon. These constants were evaluated graphically by the present author and are shown in Fig. 1, which also includes the strength values of cast iron in reference to carbon and silicon content already given by Coyle.* A satisfactory concordance is apparent, and it is seen that Coyle's constants are in fact the tensile strengths for the 1-in. test bar. But as Coyle gives only one value for the exponent m, namely, -0.495 (*i.e.*, $-\frac{1}{2.02}$), the slope of his curves in logarithmic co-ordinates is therefore always the same, *i.e.*, the percentage diminution in strength is equal for each grade of cast iron.

H. Jungbluth and P. A. Heller used this Paper as a basis. After showing that not only the tensile strength but also the transverse strength and Meyersberg's "flexure coefficient"† ("Verbiegungszahl") follow the same law," they succeeded[48] later in establishing that in the diminution in strength of a test bar not the constant c, that is the strength of the 1-in. bar, but the exponent m, representing the gradient of the curve, is the criterion determining the sectional sensitivity. In the following, therefore, sectional sensitivity implies only this diminution in strength as expressed by Coyle's exponent m, and has no reference to its absolute value (*i.e.*, without reference to Coyle's constant c). Figs. 2 and 3 summarise the relations. It is seen that cast irons with high carbon and silicon contents not only have a smaller Coyle's constant c, that is, a lower strength in the 30-mm. test bar (Fig. 2), but also a greater exponent m (or a as Heller and Jungbluth have denoted it), *i.e.*, they have a greater percentage diminution in strength compared with a 30-mm. test bar (Fig. 3). Naturally the relations between bar diameter, strength and gradient are not very accurate, as there is a certain tolerance due to the moulding, casting and test conditions.

Table I.—*Wall-thickness Exponent "a" for Tensile Strength according to Experiments of A. Koch and E. Piwowarsky.*[43]

Melt No.	C.	Si.	C + Si.	Mn.	P.	S.	$-a$ at casting temperature	
							1,440 deg.	1,340 deg.
1	3.51	1.64	5.15	0.40	0.060	0.042	0.67	0.72
2	3.44	2.03	5.47	0.38	0.061	0.043	0.44	0.43
3	3.40	2.51	5.91	0.39	0.064	0.040	0.36	0.34
4	3.12	1.65	4.77	0.40	0.069	0.043	0.30	0.24
5	3.12	2.00	5.12	0.41	0.076	0.042	0.30	0.31
6	3.03	2.52	5.55	0.38	0.072	0.041	0.28	0.35
7	2.82	1.63	4.45	0.47	0.066	0.041	0.22	?
8	2.84	1.86	4.70	0.47	0.066	0.040	0.35	0.31
9	2.85	2.23	5.08	0.48	0.068	0.044	0.49	?
10	2.59	1.30	3.89	0.43	0.069	0.045	?	?
11	2.61	1.69	4.30	0.45	0.068	0.046	?	0.22
12	2.63	2.24	4.87	0.41	0.073	0.042	0.21	0.43

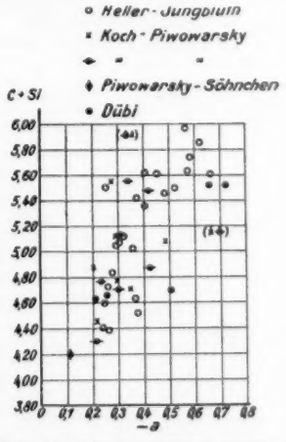

Fig. 7.—Relationship between C + Si and a.

Nevertheless, probability curves should enable the range of variation and the modulus values to be determined sufficiently accurately so that the diminution in strength of test bars can be expressed numerically, a task which, however, could only be carried out by co-operative research. This part of the problem of sectional sensitivity can therefore be regarded as solved.

For the transverse strength, diagrams similar to those for tensile strength can also be developed, as well as for the Brinell hardness and other strength properties. Fig. 4 shows, *e.g.*, the relationship between the exponent a for the tensile strength and the exponent c for the Brinell hardness,* as plotted by *P. A. Heller and H. Jungbluth.*[48] From the diagram the known fact can be deduced that the percentage differences in the Brinell hardness of different wall thicknesses are not as great as those for the tensile strength. The Brinell hardness does not differ as much as the tensile strength, which is also shown by Fig. 5 from *R. Mailänder und H. Jungbluth.*† This result is very important, as much data on cast iron devoid of sectional sensitivity are based on the Brinell hardness, which should be checked occasionally. Fig. 6 shows finally the relationship between the exponent a for the tensile strength and the exponent b for the transverse strength, also according to *P. A. Heller and H. Jungbluth.*[48] This curve shows that the transverse strength, too, does not vary as much as the tensile strength, which again agrees with Fig. 5. However, it has to be borne in mind that the tensile strength was determined on machined and the transverse strength on unmachined test bars.

P. A. Heller and H. Jungbluth[48] used, in addition to their own data, figures given in British and American literature.[30 39] It is still necessary to investigate how far the Paper of *A. Koch and E. Piwowarsky*[43] can be correlated with P. A. Heller and H. Jungbluth's theory. These investigators cast bars of plain cast iron of 22 mm., 37 mm., 52 mm., and 67 mm. dia. This material, being made in the Brackelsberg furnace by a different melting process, was expected to give values not agreeing with those of Heller and Jungbluth. In addition to the influence of different carbon and silicon contents the influence of the pouring temperature was also studied.

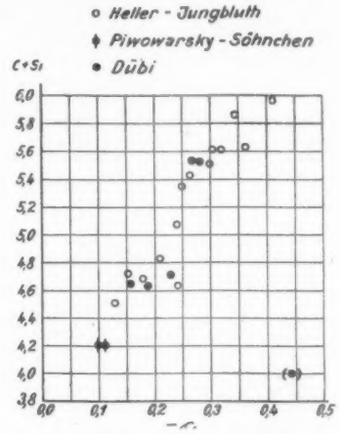

Fig. 8.—Relationship between C + Si and c.

The author has calculated (Table I) the exponents showing the influence of wall thickness, only the figures for tensile strength being usable. The value for the thinnest bar did not conform with the curve for transverse strength, because the bar was tested with its skin, while all other pieces had been turned down to 30 mm. dia., thus having the skin removed. No data were given of the dimensions of the test pieces for tensile tests, so that it cannot be determined whether on pieces of different diameter an equivalent portion of the diameter was each time tested, as ensured by P. Heller and H. Jungbluth.[48] Nevertheless, the values found agree satisfactorily with those obtained by P. A. Heller and H. Jungbluth[48] and included in Table II. This is seen in particular on plotting these values against the total C + Si, as in Fig. 7. As the influence of the pouring temperature upon a is practically negligible, the whole of the numerical data can be used (the test pieces marked × in Fig. 7 were poured at 1,440 deg. C.), and those marked ⊖ at 1,340 deg. C.

It is remarkable that a rising silicon content in melts 1, 2 and 3 did not cause an increase

Table II.—*Wall-thickness Exponents "a" for Tensile Strength and "c" for Brinell Hardness according to Experiments of P. A. Heller and H. Jungbluth.*[49]

	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.	M.	N.	O.
C + Si ..	5.51	5.07	5.42	4.83	4.52	4.72	5.61	5.86	5.61	4.69	5.36	5.97	4.63	5.63
$-a$ ..	0.26	0.31	0.38	0.275	0.36	0.26	0.46	0.63	0.67	0.30	0.41	0.57	0.37	0.58
$-c$ ..	0.300	0.242	0.264	0.208	0.129*	0.152	0.306	0.347	0.321	0.180	0.250	0.415	0.242	0.365

	P.	Q.	R.	S.	T.	U.	V.	W.	X.
C+Si	5.74	5.50	5.62	4.39	4.60	5.06	5.12	5.45	4.41
$-a$	0.59	0.53	0.41	0.27	0.25	0.30	0.32	0.49	0.24

* Heller and Jungbluth gave the value 0.392 for this material. On re-examination of the figures, particularly by a re-check of Fig. 10 in the Paper cited,[49] the writer finds that it is more advisable to regard the value for the 20-mm. test bar as anomalous and thus reject it in drawing the curve. The new curve then gives the c-value included in the table. If this assumption is not accepted, this c-value must also be taken as anomalous and omitted.

* "Iron Age," **124** (1929), pp. 6–7; "Proc. Am. Soc. Test Mat.," **29** (1929), II, pp. 87–93.

† "Glasserei," **17** (1930), pp. 473–81, 587–91; "Kruppsche Monatshefte," **12** (1931), pp. 301–330; "Stahl u. Eisen," **50** (1930), pp. 1305–07.

* The writer employs the same exponents for the different properties as Heller and Jungbluth.

† "Technische Mitteilungen Krupp," **1** (1933), pp. 83–93.

but a reduction in the sectional sensitivity, which is in opposition to all previous knowledge. The corresponding points for melts 1 and 2 are picked out in Fig. 7 by a vertical stroke; these must obviously be omitted from the series of points. Some points are also obtained from the data of E. Dübi.[49 51] Without specifying his melting apparatus, he cast together with test boxes (which will be dealt with later) test bars of plain cast iron with diameters of 30 mm. and 50 mm.

TABLE III.—*Wall-thickness Exponent "c" for Brinell Hardness according to Experiments of E. Piwowarsky and E. Söhnchen.*[37]

Type.	No.	C.	Si.	C+Si.	Mn.	P.	S.	Ni.	Cr.	−c.	Remarks.
S G	1	2.67	1.25	3.92	0.06	0.040	0.020	—	—	0.056	
S B	2	2.71	2.66	5.37	0.07	0.065	0.026	—	—	0.116	
S O	3	2.53	2.15	4.68	0.27	0.063	0.020	—	—	0.081	
S M	4	2.64	2.23	4.87	0.11	0.565	0.014	—	—	0.205	
S C	5	2.71	1.46	4.17	0.06	0.065	0.032	1.25	—	0.045	
S D	6	2.69	1.46	4.15	0.06	0.068	0.032	2.50	—	0.015	
—	—	—	1.50	—	—	—	—	0.00	—	0.060	Constructed.
S Q	7	2.60	2.13	4.73	0.12	0.045	0.013	—	0.32	0.133	
S R	8	2.40	2.12	4.52	0.05	0.048	0.007	—	0.60	0.097	

Naturally it is rather presumptive to calculate from only two diameters the sectional sensitivity; it can nevertheless be done, as shown by Figs. 7 and 8, which indicate that the results conform entirely with those already deduced. Only one *c* value does not fall within the curve at all. As the corresponding *a* value is positive, it may be assumed that this cast represents some intermediate stage. It must be admitted that the values so obtained are very scattered, but there is a certain numerical regularity. It may therefore be claimed with some justification that these investigations have reached a certain stage of finality.

The above investigations on the fundamental laws of sectional sensitivity have been amplified by further work on test bars of *alloyed* cast iron in order to determine the influence of alloying elements on the sensitivity factor, particularly by the work of *E. Piwowarsky and E. Söhnchen*.[37 46] In the first Paper[37] square test bars of 15 mm., 30 mm., 40 mm., 60 mm., and 90 mm. side and 90 mm. long were cast. The shape of these bars differs considerably from those used by P. A. Heller and H. Jungbluth, who used round bars and made a point of maintaining a ratio of length to diameter of 20: 1, while in the Paper mentioned[37] this ratio varied from 6: 1 to 1: 1. Besides, the materials were melted in oil-fired crucibles, and their preparation thus differs considerably from that employed by Heller and Jungbluth. Carbide content and Brinell hardness, as well as the influence of silicon, aluminium, nickel, and chromium, were studied.

In other Papers[46 52] the authors amplify this work, and used round bars of 20 mm., 30 mm., 40 mm., and 60 mm. diameter and 650 mm. long, thus approximating closely to the conditions chosen by Heller and Jungbluth. The heats were carried out in a 400-kw. electric-arc furnace, thus again with different means as employed by Heller and Jungbluth. The influences of silicon, phosphorus, aluminium, nickel, chromium, and molybdenum were studied and the tensile strength, Brinell hardness and carbide content also measured. Here also the present writer has deduced from the published curves

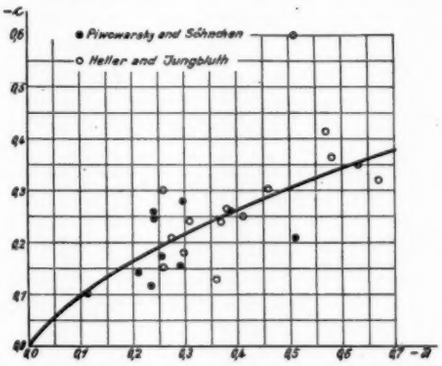

FIG. 9.—RELATIONSHIP BETWEEN EXPONENTS *a* AND *c*.

TABLE IV.—*Wall-thickness Exponent "a" for Tensile Strength and "c" for Brinell Hardness according to Experiments by E. Piwowarsky and E. Söhnchen.*[46]

No.	C.	Si.	C+Si.	Mn.	P.	S.	Al.	Ni.	Cr.	Mo.	−a.	−c.
1 ..	3.00	1.20	4.20	0.39	0.149	0.012	—	—	—	—	0.114?	0.110
2 ..	3.00	1.20	4.20	0.43	0.245	0.008	—	—	—	—	—	0.102
3 ..	2.95	1.18	4.13	0.45	0.639	0.008	—	—	—	—	—	0.179
4 ..	2.85	1.05	3.90	0.44	0.863	0.006	—	—	—	—	0.510?	0.600?
18 ..	3.10	3.56	6.66	0.54	0.121	0.012	—	—	—	—	?	?
5 ..	3.08	1.30	4.38	0.44	0.070	0.018	0.21	—	—	—	0.292	0.154
6 ..	2.98	1.48	4.46	0.41	0.076	0.016	0.47	—	—	—	0.386	0.260
7 ..	2.96	1.26	4.22	0.42	0.072	0.014	—	1.85	—	—	0.296	0.280
14 ..	3.28	0.62	3.90	0.54	0.093	0.032	—	3.10	—	—	0.209	0.142
13 ..	2.82	1.12	3.94	0.42	0.774	0.013	—	1.70	—	—	0.510	0.208
15 ..	3.32	3.12	6.44	—	—	—	—	—	0.57	—	0.236	0.115
16 ..	3.32	2.95	6.27	0.48	0.100	0.023	—	—	0.99	—	0.256	0.172
9 ..	3.04	1.28	—	0.45	0.070	0.015	—	—	—	0.27	0.242	0.258
10 ..	2.98	1.22	—	0.41	0.076	0.010	—	—	—	0.50	0.242	0.246

From the graphs the present author has obtained the *c* values, having determined the exponents for the reduction in Brinell hardness with such accuracy as was permitted by the original tables (see Table III). It is seen that the *c* values in general are much lower than those of Heller and Jungbluth. The present author considers this due to the fact that in the case in question the pouring conditions approximated more closely to those of large castings, for which the sectional sensitivity is known to be smaller than that of separately-cast bars. In addition the effect of silicon (heats 1, 2, and 3) and particularly of phosphorus (heats 3 and 4) in increasing the sectional sensitivity is also clearly brought out. Nickel decreases the sensitivity value (heats 5 and 6), while chromium (heats 7 and 8) does not appear to have much effect for there is only a slight difference between the exponents (0.133 against 0.097).

the sectional exponent *a* for tensile strength and *c* for the Brinell hardness with the degree of accuracy possible; these are given in Table IV. If these values are compared with those of the first Paper it is seen at once that in general they are higher, which is undoubtedly due to the fact that a different bar shape was used. It is of interest, in spite of the difference in melting conditions, to attempt to correlate the values[46 52] found by Piwowarsky and Söhnchen and those of Jungbluth and Heller.[44] This is naturally only possible for the unalloyed materials, and for these only in so far as the phosphorus content remains within the limits prescribed by Heller and Jungbluth. Therefore as regards analysis only the melts No. 1, 2, and 18 are of value, of which No. 18 is, however, useless, as the wall-thickness exponent could not be determined sufficiently accurately. For melt No. 2 no values for the tensile strength were given; the exponent *a* for melt No. 1 is in perfect accord with the values found by *Jungbluth and Heller*[44] and *Koch and Piwowarsky*,[45] respectively, as a glance at Fig. 7 will show.

For the Brinell hardness the exponent *c* of melts Nos. 1 and 2 can be used, and its magnitude also agrees with the values of Heller and Jungbluth, as shown by Fig. 8. The curve is extremely satisfactory. A second observation of a general nature is not without interest. If all exponents *a* and *c* (Fig. 9) are compared without regard to the fact that *Heller and Jungbluth*[44] employed unalloyed and *Piwowarsky and Söhnchen*[46] alloyed material, it is seen that these values are also in satisfactory accord. The curve drawn through the various points conforms with that already given by *Heller and Jungbluth*.[44] Regarding the influence of the alloy elements, they confirm the facts already deduced in the first Paper.[37] Nickel (melts 7 and 14) reduces the sectional sensitivity, probably because the silicon content can be lowered. Aluminium (melts 5 and 6) and phosphorus (melts 1, 2, 3, and 4) raise this factor, phosphorus even if the casting contains 1.7 per cent. nickel (melt 13). Chromium (melts 15 and 16) and molybdenum (melts 9 and 10) have but little influence. It was not possible to estimate numerically the influence of silicon, because melt 18 did not allow the calculating of the exponent.

The numerical values published by Piwowarsky and Söhnchen in both their Papers are of great importance, because they provide the first numerical data indicating the influence of alloy elements on the sectional sensitivity. But these two investigators will themselves agree with the writer that their experiments may be regarded merely as tentative ones which require amplification by others of greater precision.

(To be concluded.)

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Publication Received

Industrial and Residential Handbook of the County Borough of Wolverhampton. Published by the Wolverhampton Industrial Development Association, Town Hall, Wolverhampton.

Anyone receiving this book can count themselves fortunate, for seldom, if ever, has the development department of a municipality produced such a charming brochure. The binding is carried out in a black flocked-paper and on the front is a highly-coloured picture of the town, beneath which, picked out in silver, is the title of the book. The contents have been well chosen and statistics are well balanced by descriptive matter and excellent photographs. The main attraction from a business point of view of this town is the low level of the rates levied per head of population. Actually the rates are only 11s. 6d.

Iron and Steel Institute

AUTUMN MEETING AT DÜSSELDORF

The Autumn Meeting of the Iron and Steel Institute, as previously announced, will be held in Düsseldorf from September 21 to September 26, by the kind invitation of the Verein deutscher Eisenhüttenleute, acting on behalf of the German iron and steel industry. An influential and representative Reception Committee has been formed in order to carry out the arrangements of the meeting, with Generaldirektor Dr.-Ing. E.h. Fritz Springorum, President of the Verein deutscher Eisenhüttenleute, as Chairman. Dr.-Ing. Otto Petersen, Director of the Verein deutscher Eisenhüttenleute, has kindly consented to act as Honorary Secretary. Arrangements will be made for members wishing to do so to travel in a party from London on Sunday, September 20, and special trains will be engaged for this purpose.

Provisional Programme

Two morning sessions will be held for the reading and discussion of Papers, the first on Monday, September 21, in the Schauspielhaus, Karl-Theodor-Strasse 2, and the second on Tuesday, September 22, in the Eisenhüttenhaus, Ludwig-Knickmannstrasse 27. On the afternoons of these days visits will be arranged to works and places of interest in and around the city of Düsseldorf.

On the evening of Monday, September 21, the visitors are invited by the Reception Committee to attend a banquet which will be followed by dancing.

On the evening of Tuesday, September 22, the party will visit the Kaskade, Schadowstrasse, for an informal reunion which will include a cabaret and dancing.

The whole of Wednesday, September 23, will be devoted to visits to works in the Lower Rhine district, where the members will be entertained to lunch. Members and ladies will meet at Duisburg and return from there to Düsseldorf by Rhine steamer. Dinner will be taken on the steamer.

On Thursday, September 24, visits will be paid to works in the Cologne, Dortmund and Mülheim districts. The evening will be left free for members to make their own arrangements.

On Friday, September 25, visits will be made to works at Essen and Dortmund. In the evening members and ladies will be entertained to dinner at the Villa Hügel, near Essen, by kind invitation of Herr Dr. Krupp von Bohlen und Halbach.

On Saturday, September 26, the party will leave Düsseldorf by special train for Rüdesheim, where lunch will be served. During the afternoon the party will proceed by steamer to Coblenz, returning by train to Düsseldorf in the evening.

Arrangements will be made for members wishing to do so to return to London on Sunday, September 27, and special trains will be engaged for this purpose.

Extensions of the programme to include excursions to Siegen (foundries and roll casting) or to Saarbrücken (visits to important iron and steel works) are being arranged in order to enable members to visit works in these districts. Members taking part in these excursions will leave Düsseldorf on Sunday, September 27, and probably spend two days at Siegen or Saarbrücken, so that the return journey for those travelling to London may be made on Wednesday, September 30.

Itinerary

For members travelling from London, arrangements have been made with the Southern Railway Company for a special train to leave London (Victoria Station) about 10.0 a.m. on Sunday, September 20. The party will travel via Dover and Ostend. Arrangements have also been made for a special train from Ostend to Düsseldorf, where the party will arrive at about 9.0 p.m.

Financial Regulations in Germany

Currency Regulations.—Strict regulations are in force in Germany as regards both the import and export of German and foreign currency, and the purchase and use of German currency obtained at the favourable "*Register Mark*" rate of exchange. The regulations are very strictly enforced, and it is essential that members should acquaint themselves with them. In practice, these regulations, if adhered to, cause no difficulty.

"*Register Marks.*"—Travellers in Germany are entitled to purchase Reichmarks (Rm.) at a favourable rate of exchange (approximately 21 Rm. to £1 as against approximately 12.50 Rm. to £1 current exchange rate). The use of Reichmarks (Rm.) obtained at this favourable "*Register Mark*" rate of exchange is confined to the payment of travelling, hotel and catering expenses, as well as other daily expenses incurred in connection with the traveller's personal requirements. The amount obtainable by each traveller at the "*Register Mark*" rate of exchange is limited to 50 Rm. per day, including the days of arrival and departure. Members availing themselves of the travel and hotel arrangements provided by the Institute will generally only require sufficient German currency to cover other expenses which are not included in the inclusive charges (*e.g.*, beverages, extra travelling and minor personal disbursements). Members wishing to obtain currency at the "*Register Mark*" exchange rate for payment of expenses coming within the permissible categories other than such expenses as are covered by the Institute are advised to purchase Travellers Cheques from a Bank or Travel Agency, stating that they wish to avail themselves of the "*Register Mark*" facilities up to a maximum of 50 Rm. for each day of the visit. Such Travellers Cheques are obtainable in amounts of 25, 50 and 100 Rm., and can be cashed in Germany on production of the holder's passport. Foreign currency can only be exchanged at the less favourable current rate.

Import and Export of Currency.—Not more than 10 Rm. German currency in cash may be taken into Germany by any individual and not more than 10 Rm. in coins (no notes)—or the same amount as was taken in, whichever is the least—may be taken out. It is therefore advisable to avoid arriving at the frontier on the return journey with greater sums, although facilities for return of surpluses through a bank are available. Travellers Cheques are not included. Foreign currency (but not Travellers Cheques) must be declared on entering Germany, and a certificate of the amounts obtained; in this case sums not exceeding these amounts can be re-exported.

Indemnity.—The Institute has obtained facilities which will enable all payments (within the permissible categories) made on behalf of members to be made at "*Register Mark*" rate of exchange, and as a result of this special concession it has been possible very substantially to reduce the cost of the meeting to those participating. In order to enable this special concession to be obtained it will be necessary for Members to certify that they will adhere to the regulations. Special banking facilities for the cashing of Travellers Cheques and for exchange of foreign currency will be arranged at Düsseldorf.

Passports.—Passports are necessary for the journey to Germany. Members should see that their passports have been correctly endorsed and that the period for which they are valid has not expired.

Use of Cast Iron in the Chemical Industry*

By H. L. MAXWELL

Commercial Grey Cast Iron

Cast iron, because of its machinability and low cost, is widely used in chemical equipment. Its ready response to alloying and heat-treatment makes it adaptable to a wide range of plant service conditions. Ordinary grey cast iron has approximately the following range of composition:—T.C, 2.60 to 3.70 per cent.; Si, 0.75 to 2.80 per cent.; Mn, 0.60 to 0.90 per cent.; S, 0.04 to 0.10 per cent., and P, 0.60 per cent. max.

When castings of this composition are poured into sand moulds and allowed to cool slowly, the microstructure will be found to be a matrix of free iron (ferrite) and combined carbon as lamellar pearlite, which contains about 0.83 per cent. combined carbon. Dispersed throughout this matrix will be found flakes of graphitic carbon, which result from the decomposition of part of the cementite. There will also be bluish-grey coloured islands of manganese sulphide. If the phosphorus is present in excess of 0.20 to 0.30 per cent. a phosphorus-rich eutectic, angular and stippled, will appear as segregations. If the composition is high in both carbon and silicon the size of the free graphite flakes will be larger. A fracture will show the metal to be coarse grained and of low strength because of the large graphite flakes that interrupt the normal continuity of the stronger iron in the matrix.

Factors Limiting Application

One of the factors that limit the use of ordinary cast iron in high-temperature chemical service is that the graphitisation of the metal does not attain equilibrium when the castings are cooled in the mould. As a result, after the machined casting is placed in other than low-temperature service, graphitisation will probably be resumed and the casting will increase in volume and warp.

A second disadvantage of ordinary coarse-grained cast iron, particularly when it is exposed to corrosive chemicals, is that the large areas of graphite permit an infiltration of the corrosive constituents into the body of the casting and thereby contribute to early failure. A striking example of this type of failure was found in cast-iron hearths of a Herreshoff furnace used to calcine a paste of spent lime and adsorbed caustic. Two reactions had taken place: (1) the caustic had gained access through the coarse graphite flakes to approximately 30 per cent. of the thickness of the hearth casting, causing cracking, and (2) the whole surface of the metal was attacked, owing to the action of free caustic on the silicon in the cast iron. Both types of attack can be reduced by lowering the silicon content to a point where there is just sufficient silicon to graphitise the excess carbide and leave a eutectoid matrix of lamellar pearlite. Cast iron with this type of microstructure shows a two-fold improvement:—the graphite is more finely divided and hence more resistant to chemical attack, and the matrix has not only higher strength but is more nearly continuous as well.

One of the principal applications of alloy cast iron is in high-temperature service. Where equipment is maintained at high temperature over a considerable period of time, it is subject to failure either by increase in volume or by scaling. It will be recalled that the increase in volume of cast iron may be due to two different causes. Cast irons which increase in linear dimension under heating and then return to the original dimension on cooling are said to undergo expansion. If, on the other hand, the heating of the cast iron results in physical and chemical changes in the metal structure, the dimensions of the piece may be permanently increased. This phenomenon, known as "growth," often occurs in alloys that have high combined carbon and were poured in the foundry under conditions such that normal graphitisation did not take place on cooling. On subsequent heating, as with chemical equipment maintained at temperatures from 550 to 700 deg. C., the combined carbide is given an opportunity to decompose into iron and graphitic carbon, with the result that, the latter being of low density, the volume of the metal increases.

Low-Alloy Cast Iron

There are two general methods of overcoming growth in cast iron, the first and more reliable method being to use an alloy composition such that the cementite or combined carbon will remain stable and not decompose on subsequent heating in service. Much research has been done by companies which produce alloying elements and relatively wide application is now being made of this information. A typical composition of an alloy for overcoming the growth of cast iron is as follows:—C, 3.30; Si, 1.00; Mn, 0.65; Ni, 2.00, and Cr, 0.75 per cent.

The other factor, apart from alloy additions, which tends to reduce growth in cast iron, relates to foundry practice. If the cost of the casting must be kept to a minimum, thus precluding the possibility of the addition of alloying elements, some improvement can be gained by pouring the casting at the upper limit of the permissible range of pouring temperature and allowing it to cool in the mould until the entire casting is at a temperature below a black-red heat. It is presumed that these castings are of substantial size, probably from one-half ton to several tons in weight. Small castings ranging a few pounds in weight cool so quickly as to leave large percentages of combined carbon, with the result that the castings are too hard to be readily machined. Further improvement over the high pouring temperature and long cooling time may be obtained by using a low annealing temperature, attained by holding the castings in a furnace at 760 to 820 deg. C. for from 3 to 4 hrs., so as to allow equilibrium to be reached.

Though these modifications in foundry practice, together with the annealing treatment, will, in a degree, increase the resistance of castings to growth in high-temperature service, it has been found that wherever the cost can be justified it is desirable to use alloy additions.

Whereas cast iron may not be properly classed as a corrosion-resistant material as compared with high-alloy steels or special alloys, it does possess sufficient immunity to make its use economical in many instances where corrosion is a factor. Appreciable improvement may also be made with alloy additions. Austenitic cast irons, which show considerable inertness towards certain types of chemical attack, will be discussed later.

Alloy additions to cast iron, made in order to increase resistance to corrosion, must be carefully adjusted to the actual conditions to be met, and the composition must be correctly balanced. It often happens that a particular composition will give a marked improvement under one set of conditions, whilst in another application the rate of corrosion will be increased.

Laboratory tests give indications, but they cannot be relied upon with certainty until checked in plant equipment. This is because it is practically impossible to reproduce plant conditions exactly in the laboratory. Wherever possible, laboratory tests should be made in plant liquors, since an unsuspected impurity may be a primary cause of failure. Nickel-chromium additions are usually beneficial, although a small amount of chromium alone is often detrimental to corrosion resistance. The improvement in low-alloy nickel-chromium irons is probably due, in the main, to better physical properties.

Resistance to Caustic Attack

Caustic pots are commonly made from cast iron. The ordinary grade of cast iron shows a relatively rapid rate of deterioration in this service, the attack being primarily due to the reaction of the silicon in the metal with strong, hot caustic. Two classes of materials are being successfully used in such applications. One of these is Lyncast low-silicon cast iron, the composition of which is approximately:—C, 3.45; Si, 0.75; Mn, 0.30; S, 0.08, and P, 0.10 per cent.

The increased resistance of this material to caustic attack is due primarily to the lower silicon as compared to ordinary cast iron. Low-alloy cast irons, widely used for caustic service, may be either a straight nickel cast iron or a nickel-chrome iron of low silicon content, the former being usually preferred. Compositions recommended by the International Nickel Company are as follow:—

	(1)	(2)
	per cent.	per cent.
C	3.50	3.30
Si	0.50	0.70
Mn	0.50	0.50
Ni	2.00	1.50
Cr	0 to 0.30	0.60

A particular application where a low-alloy cast iron composition, selected because of its low growth, showed definite economic advantage over ordinary cast iron, may be of interest. Autoclave inserts, 11 ft. 4 in. by 3 ft. 9 in. by 1¼ in. thick, and weighing 6,700 lbs., were made of ordinary grey cast iron and operated at 382 deg. C. The early failure of these parts prompted a study of the problem to determine a more economical material of construction. The condition and nature of the metal failures indicated that the fractures resulted from the combined effect of expansion or growth, and also to coarseness of structure in the metal wall. The relatively large weight of the insert and also the conditions of corrosion eliminated high-alloy materials, such as stainless steel, from consideration on account of cost. The best probability lay in the use of high-quality low-alloy cast iron, and the following composition was recommended:—Si, 1.0 to 1.25 per cent.; Mn, 0.8 per cent.; S, 0.08 per cent.; P, 0.25 per cent.; Ni, 1.00 to 1.25 per cent.; Cr, 0.40 to 0.50 per cent.

It will be noted in the above analysis that the percentage of nickel is roughly 2½ to 3 times the percentage of chromium and, further, that since the silicon and nickel are both graphitising in effect, the silicon is lowered from the normal as far as possible. The purpose of this is to equalise the two opposing reactions affecting the stability of the combined carbon. Frequently, silicon may be reduced in the absence of chromium by an amount approximately equal to half of the nickel added, and greater thermal stability may be expected owing to the greater solubility for carbon that nickel possesses, accompanied by an inherent resistance to oxidation. In following these castings through the foundry it was found desirable to add 25 per cent. of heavy steel scrap in order to bring the silicon and sulphur of the pig-iron within the proper limits for alloy conditions.

The low-alloy cast-iron vessels have now been in service approximately two years and have shown improvement in operating life. The initial cost of the low-alloy iron was 2¼d. per lb.,

* A Paper read before the Chemical Engineering Congress of the World Power Conference.

as compared with 2d. for the plain cast iron formerly used. This 25 per cent. increase in first cost is too frequently the reason why alloy iron is not used. The increase in cost is small as compared to the savings gained from longer life of the equipment in the present instance, where the life increases by six to one. After debiting the increase in first cost of the low-alloy castings, the maintenance has been reduced from £214 per unit per year to £45 per unit per year through the use of low-alloy cast iron.

An example of growth in ordinary cast iron was recently noted in steam turbines which had been operated satisfactorily for 10 to 12 years. Later the operating conditions were altered so that 170 lbs. per sq. in. steam pressure plus over 100 deg. Fah. superheat raised the actual operating temperature to approximately 500 deg. Fah. Following this change it was found that the cast iron was growing at the rate of 0.017 in. per year. The use of an alloy cast iron in the original body castings would have eliminated this difficulty. Cast steel was, as a matter of safety, used in the replacements.

High-Duty Cast Irons

Within the past ten years irons have been developed which have much higher strength than was formerly considered possible for cast iron. Tensile strengths above 22 tons per sq. in. are regularly produced, and in some cases values of 31 tons or above have been reached, depending on the thickness of section. These materials are higher in density than ordinary cast iron, are more nearly uniform in structure, and may be either with or without alloy additions. Cast iron of high strength has usually a low carbon-content, ranging between 2.5 and 3.1 per cent. total carbon, and the graphite is present in small, evenly distributed particles. Representatives of this class of cast iron have typical compositions, as follow:—

	Ni-Tensyl iron. Per cent.	Meehanite metal. Per cent.
T.C	2.65–2.95	2.40–2.70
Si	1.50–2.00	1.10–1.50
Mn	0.50–0.90	0.65–1.00
P	0.15 max.	0.10–0.20
S	0.12 max.	0.05–0.14
Ni	2.00–2.25	—

Ni-Tensyl iron is essentially produced by tapping from a furnace a melt which would give white iron castings if poured directly, and partially decomposing the cementite by additions of the graphitising elements silicon, and nickel, during tapping. In general, it may be stated that the tensile strength of this material is raised as the total amount of silicon and nickel, in proper ratio, is increased. In specific instances as high as 2.75 per cent. silicon and 4.0 per cent. nickel are sometimes added. Small amounts of chromium and molybdenum are also used. One grade of Meehanite metal is produced by treating the molten metal with calcium silicide, and the composition is such that a white iron would be produced if the calcium silicide were not added. High-strength irons may be further improved and the hardness varied by oil-quenching from above the critical range and tempering at suitable temperatures. Applications for these materials include gears, turbine casings, rollers, bushings, oil-well machinery, drawing dies, etc.

Hard Cast Irons for Resistance to Wear

For applications where resistance to abrasion is an important factor, hard cast irons are extremely useful. Though it is generally recognised that a pearlitic iron is more resistant to wear than a ferritic iron, it is necessary to obtain a harder material before severe abrasion can be met without difficulty. Hardness does not vary directly with resistance to abrasion; however, increased hardness in cast iron results in greatly improved performance in applications involving severe wear. Alloy cast irons have been developed which, whilst showing sufficient resistance to shock for ordinary service, have a hardness ranging upward to 700 Brinell. Two martensitic cast irons of this class are Ni-Hard and Diamite. The composition of Ni-Hard lies within the following range:—C, 2.75 to 3.6; Si, 0.50 to 1.5; Mn, 0.20 to 0.7; Ni, 4.40 to 4.6, and Cr, 1.40 to 1.6 per cent.

These alloys have found wide use in applications such as pump casings, handling ashes or sand, ash sluice liners, dredging equipment, grinding discs, conveyor screw-flights, etc., and have replaced white cast iron in many instances.

For purposes not requiring such a high degree of resistance to wear, straight chromium additions up to 1.0 to 1.5 per cent., or low nickel-chromium additions in which the nickel-chromium ratio may be reduced to as low as ½ to 1 in special cases, together with balanced variations in silicon, are frequently helpful. Nickel, when present alone, tends to combine with and harden the pearlite matrix, which, as the nickel is increased to 3.0 per cent, is transformed into sorbite, and even to martensite with amounts above 5.0 per cent. Free carbide is reduced or eliminated at the same time. Molybdenum additions up to 1.5 per cent. are beneficial. A test was made in which 30 gear blanks were prepared under identical conditions, 15 of regular cast iron and 15 of the same iron with 0.67 per cent. molybdenum. The Brinell hardness of the molybdenum iron was 231 on the side of the rim and 216 on the face of the rim, as compared to 211 and 192 for regular cast iron. No appreciable effect on machinability was noted.

It may be desired to obtain the maximum possible machinable hardness by direct alloying. Attention is called to the fact that the composition must be adjusted to correspond to the thickness of the sections involved. Thin sections are hardened to a greater degree than heavy sections by the same alloy additions. For instance, a cast iron containing 3.35 per cent. carbon and 1.25 per cent. silicon showed a hardness of 250 Brinell in a ½-in. section, with 0.75 per cent. nickel and 0.25 per cent. chromium. Using the same nickel-chromium ratio in a 1½ in. section it was necessary to add 1.35 per cent. nickel and 0.45 per cent. chromium to attain the same hardness. Failure to take thickness of section into account has sometimes resulted in the elimination from consideration of an entirely satisfactory alloy composition. This factor is usually controlled by adjusting the silicon content rather than the total alloy addition. Low-silicon or low-carbon irons respond better to hardening by nickel-chromium additions. In applications where surface hardening is sufficient, treatments such as nitriding allow Brinell hardnesses up to 900 to be obtained. This type of surface is, of course, not suitable where corrosion is also a factor.

In addition to the use of chromium and nickel in cast iron for use in chemical equipment, there are also high-silicon types of alloy iron that have been employed with varying degrees of success.

High-Silicon Cast Iron

The British Cast Iron Research Association in 1928 introduced a series of heat-resistant cast irons called Silal, which covers normally a range of 4 to 6 per cent. silicon, with a carbon-content from 1.6 to 2.8 per cent. These materials are not of high strength and they possess less resistance to shock than does grey cast iron. Above 9 per cent. silicon the difficulty of machining these high-silicon irons increases rapidly, and between 10 per cent. and 14 per cent. silicon, in which range increased acid resistance is developed, the metal becomes brittle and unworkable except by grinding.

There is some indication that the addition of chromium to silicon cast iron markedly improves its resistance to high temperatures. It was first shown experimentally that 5 to 6 per cent. silicon cast iron, with 4 per cent. chromium, had very good resistance to high temperatures, but this alloy had a distinct disadvantage in that it was practically impossible to machine it, even after an annealing heat-treatment. By lowering the chromium from 4 to 2 per cent. and maintaining the silicon about 5 per cent., with the total carbon in the range of 3 per cent., there is obtained an alloy that is particularly serviceable under high temperatures, such as in calcining furnaces and similar operations. Cast-iron rabble arms of roughly the above composition have been in service for three years in a calcining furnace at about 820 deg. C., with very favourable results. In describing the use of this silicon-chrome cast iron for high-temperature service, it is not meant to suggest that this material is equal in quality to the high-chrome cast materials, as, for instance, 28 per cent. chrome, 3 per cent. nickel and 0.4 to 0.9 per cent. carbon. These latter materials, which cost much more, have a distinct application under extremely severe conditions as, for instance, in corrosive gases above 900 deg. C. However, silicon-chromium alloys which are available at about 2¾d. to 3d. per lb. show definite economies in operation in such services as rabble arms exposed to gases of low sulphur content and operating at moderate temperatures. They are also being used to some extent in coke-oven doors and in gas-generator equipment.

High-silicon irons containing 13 to 16 per cent. Si have been used for the past 30 years where resistance to acid was required. Silicon adds little to the corrosion resistance of iron until the range of about 12 per cent. silicon is reached, at which a sudden increase occurs, accompanied by a marked change in physical properties, the alloy becoming hard and brittle. American alloys known as Duriron, Tantiron, Antaciron and Corrosiron are in the general range of 13 to 16 per cent. silicon, as well as Ironac, Therimsilid and others on the Continent. There appears to be no advantage in exceeding about 16 per cent. silicon. These alloys show excellent resistance to sulphuric and nitric acid, but are attacked by hydrochloric acid. Their use is limited by their susceptibility to thermal and mechanical shock. A recent development known as Durichlor contains, in addition to the silicon, about 3 to 4 per cent. molybdenum and 0.25 per cent. nickel. The resultant metal has about the same physical properties as Duriron, but is markedly superior in its resistance to hydrochloric acid. The corrosion rate of Durichlor in boiling 20 per cent. HCl, on the basis of a 240-hr. test, is approximately 0.0087 in. penetration per month. Under the same conditions of acid concentration, temperature and time of test, the corresponding corrosion rate on Duriron is 0.110 in. penetration per month.

Austenitic Cast Irons

A discussion of alloy cast irons would not be complete without a brief reference to austenitic cast iron, which was developed about twelve years ago and has since found wide application in the process industries.

	Regular Ni-Resist. Per cent.	Ni-Resist (copper-free). Per cent.	Nicrosilal. Per cent.	Causil. Per cent.
C ..	2.75–3.1	2.0–2.3	1.8	2.3
Si ..	1.5–2.0	0.6–2.0	6.0	2.2
Mn ..	1.0–1.50	1.0–1.50	1.0	—
S ..	0.10 max.	—	—	0.05 max.
Ni ..	12.0–15.0	15.0–20.0	18.0	18.0–21.0
Cr ..	1.25–4.0	2.50 max.	2.0	1.5
Cu ..	5.0–7.00	—	—	4.5

There are four austenitic cast irons that should be referred to as representing typical composition of this class of materials. They all have high nickel content because this is essential in order to maintain austenite as a stable phase when the castings are cooled in the mould.

This general type of cast iron was described by Dawson.[1] Other austenitic cast irons have been developed since. Vanick and Merica[2] describe corrosion-resistant cast iron of the austenitic type called Ni-Resist. Norbury and Morgan[3] describe the development and properties of Nicrosilal, which contains more nickel and silicon, but less carbon than Ni-Resist. Apart from increased nickel content, Causul differs from Ni-Resist only in degree.

Although recognising certain differences between the four austenitic irons described and their relative value in plant service, it is not considered within the scope of this Paper to appraise these differences, but rather to designate where in chemical plant service the use of austenitic alloys as a class will result in more economical operation.

The value of these cast irons lies in their resistance to heat and corrosion. The nickel, chromium, carbon and silicon combine their influence to produce a matrix that is but little affected by oxidation at high temperatures or by acid attack at low temperatures. The resistance of these alloys to scaling at temperatures up to 950 deg. C. increases with increasing silicon, and their tendency to grow under high temperatures decreases with decreasing carbon content.

The resistance of this class of metals to heat and chemical attack has resulted in a relatively wide application in chemical process equipment. Rotary and reciprocating pumps, valves, pipe lines and reaction vessels operating on sulphuric acid mixtures, caustic and many salts have been successfully used. Under high temperatures this material has shown excellent performance in resistance grids, coke-oven door frames, heat-treating stands in annealing furnaces, thermocouple sheaths and similar applications. In some equipment, as, for instance, calcining and roasting furnaces operating at 400 to 600 deg. C. in the presence of sulphurous gases, the economical use of a low-alloy cast iron is problematical, particularly if the product forms a scale and adds a condition of shock to the agitating equipment. Of course, no assurance can be given that an austenitic cast iron will improve the economies of the operation, but there is a reasonable probability that it will. The installed cost of this quality of cast iron is approximately four times that of the ordinary grade, and if the cost of installation is appreciable the economy of using the higher quality is at once recognised. Even at the risk of appearing axiomatic, it should be pointed out clearly that too often equipment is purchased on the per pound basis instead of on the cost installed basis. In most heavy chemical plants, there are some equipment parts where the material cost is 98 per cent. of the installed cost, labour representing only 2 per cent. Here, obviously, the frequency of replacement is a minor point, unless the loss of metal due to corrosion and abrasion losses introduces the problem of quality owing to metallic contamination of the product. Apart from this aspect, one of several low-cost materials might be used economically. Other installations have been encountered in equipment parts exposed to corrosion and not easily accessible, such as driving and agitation mechanisms, where the labour cost of installation is more than the cost of the replacement part. The cost of installing equipment with superior corrosion resistance is seldom more than for installing a lower-cost, shorter-life part. It should, therefore, be better appreciated that by giving more consideration, in the selection of materials, to the cost installed, further economies in production costs are possible.

Uses of Austenitic Iron

All the alloying elements listed may be varied to some degree, but there must be enough nickel present to produce a stable austenitic structure in the normal casting operation. This class of cast iron commands a higher initial cost price than the conventional cast irons, but it is well worth the difference under many service conditions. Sulphuric acid valves, sewage disposal equipment, valves and pumps in caustic service, and pump impellers used under a wide variety of conditions show definite economies when made of cast-iron compositions high in nickel and copper.

Where there are objections to the use of an alloy containing copper as, for instance, in dye vats containing sodium sulphide and sulphur dyes, it is possible and desirable to use the copper-free austenitic iron.

These compositions cast easily and are machined without difficulty, making possible their ready manipulation in the average foundry and machine shop. Their microstructure is a typical austenitic matrix with fine graphite flakes distributed throughout. The two particular properties that make austenitic cast irons useful in chemical engineering equipment are marked resistance to a wide variety of corrosive substances and resistance to scaling and disintegration by the effects of heat. The applications in chemical equipment where austenitic cast iron has shown marked economies are very numerous. This material is almost free from the type of corrosive attack that softens the surface of ordinary cast iron and causes early failure.

A Simple Test

There is a simple test by which one may obtain a fairly reliable indication whether ordinary grey cast-iron equipment can be economically replaced by an austenitic cast iron. It is desirable first to make an examination of the surface of the used grey cast-iron part to determine the nature of the surface attack. If the surface is smooth, hard, and evenly corroded it is probable that longer life would be obtained from a mottled iron casting with higher combined carbon but without alloy additions. If, on the other hand, the surface of the part is soft, indicating that the iron matrix has been dissolved away, leaving the graphite unsupported, this should be taken to indicate that increased life will be obtained by a solid solution type of matrix. This improvement is found in the austenitic alloys.

Cast-iron pump bodies, impellers and valves in weak acid service (*e.g.*, saturated solutions of carbon dioxide and/or hydrogen sulphide under pressure, or weak organic and inorganic acids) develop a soft layer of graphitic material on the exposed surfaces. This carbon residue is soft, can be readily cut with a pen-knife, and on long exposure will reach a thickness of ¾ in. In applications of this particular kind, the use of low-alloy cast iron, for instance, containing up to 2 per cent. total alloy content, is rarely, if ever, effective in reducing maintenance costs. These are applications for austenitic iron and, if any further increase in initial cost is justified, consideration should next be given to castings of 17 to 18 per cent. chromium with 0.35 per cent. carbon, or nickel-chrome low-carbon alloys (18 to 35 per cent. Ni—15 to 30 per cent. Cr), which are classified as alloy steels rather than as alloy irons.

A series of scaling tests has been made on a variety of low-alloy cast irons and also some metals including higher alloy content, up to the austenitic range. The specimens were discs 2 in. by ¼ in. The tests were made at 550 deg. C., 750 deg. C., and 950 deg. C., at 100-hr. intervals under the conditions of the furnace atmosphere as follows:—

(1) Furnace contents protected from outside air.
(2) Dry air aspirated through the furnace at the rate of 2 litres per hr.
(3) Air saturated with water vapour and aspirated through the furnace at the rate of 2 litres per hr.
(4) Illuminating gas aspirated through the furnace at the rate of 2 litres per hr.

The results are shown in the following tables:—

Experiments at 750 deg. C.—100 hrs. each.

Alloy.	Per cent. gain or loss in weight.			
	I	II	III	IV
Cast iron—no alloy added	+3.21	+1.51	+1.36	+0.03
Nickel-chrome cast iron	+2.45	+1.82	+1.17	−0.02
Ni-Resist ..	−0.31	+0.44	+0.54	+0.02

Experiments at 950 deg. C.—100 hrs. each.

Alloy.	Per cent. gain or loss in weight.			
	I	II	III	IV
Cast iron—no alloy added	−6.89	−9.45	−12.26	−14.43
Nickel-chrome cast iron	−0.79	−4.27	−7.63	−7.58
Ni-Resist ..	+1.93	+3.89	−1.90	+2.64

Ni-Resist developed and maintained a thin, dark adherent scale at both 750 and 950 deg. C. during the 100 hours of the experimental runs. The moist air used in the tests at 950 deg. C. appeared to loosen the scale to the extent that there was a slight loss of weight. It is felt that the above summary of results from these tests will suggest additional applications for these materials in a more concise manner than otherwise possible.

Conclusion

It has been the object in writing this Paper to review the properties and some of the applications of plain and low-alloy cast iron as used under mild conditions of temperature and corrosion. The material discussed also includes the intermediate alloy compositions to withstand somewhat more severe conditions as well as the high-alloy metals containing 15 to 25 per cent. of total alloy content, and which are adapted for use under high temperature and under the most severe corrosive attack. It has been the experience of the writer and others as well, that a careful review of chemical process conditions and equipment, together with a critical survey of the properties of the various grades of plain and alloy cast iron, will frequently permit the use of more of the metals described above, with resultant economies in production costs.

Northern Coke Research Committee

The annual report of the Northern Coke Research Committee contains a summary of the work carried out during the year ending December 31, 1935, in the course of which it is stated that the experimental cupola mentioned in the last annual report has been further developed during the past year. At a relative low cost it is now possible to test cokes under conditions which approximate very closely to those obtaining on the large scale. The cupola has a shaft of 9 in. dia. and is 3 ft. high. Using an air blast of 4,000 cub. ft. and a metal-coke ratio of 6:1 the cupola melts iron at the rate of 200 to 220 lbs. per hr. at a mean temperature of 1,280 to 1,360 deg. C., according to the quality of the coke employed. In a normal experiment approximately 600 lbs. of metal are melted. During the past year this cupola has been employed in close conjunction with laboratory tests in the following investigations:—(1) The effect of blending finely ground coke and coking mixtures on the properties of the coke; (2) the effect of carbonising blended coals, on the properties of the coke, and (3) the effect on the properties of the coke of carbonising similar coking mixtures in different ovens under different conditions. The results of these and further investigations are to be communicated to the technical press in due course.

1 S. E. Dawson, FOUNDRY TRADE JOURNAL, 29, 439-44, 1924.
2 J. S. Vanick and P. D. Merica, Am. Soc. Steel Treating, 18, 923, 1930.
3 A. L. Norbury and E. Morgan, J. Iron Steel Inst., 123, 413, 1931; 125, 393, 1932; 126, 301, 1932.

Capillarity as a Factor in Foundry Practice*

By Prof. ALBERT M. PORTEVIN, Ing. and Dr.h.c., and Dr. PAUL G. BASTIEN, Ing. Arts et Manufactures

[FRENCH EXCHANGE PAPER]

What is Surface Tension?

Capillarity is a property to which very little attention has been paid hitherto in foundry practice, at least not from an exact and objective point of view. Very little information is available concerning the relationships which may connect this property to the phenomena actually encountered in foundry practice.

In foundry practice its importance chiefly appears in the formation of blow-holes during the solidification of castings, in the penetration of the molten metal into the sand of the moulds or "searching," which sometimes occurs, and also in the important complex property known as "life." Surface tension also plays an important part in the action of the slags, fluxes, and so forth employed in the foundry.

In the following considerations it is not proposed to deal either with the formation of blowholes or with the action of fluxes, because that would necessitate a discussion of all the very involved problems of the evolution of gases and the chemical action of the external atmosphere on molten metals. The Paper will be confined to a discussion of the function of surface tension in the phenomena of "life" and "searching."

I.—Principles Underlying the Methods of Determining the Surface Tension of Molten Metals

The scarcity of precise data regarding the value of the surface tension of molten metals and the discrepancies existing between the figures given by different authors are chiefly due to: (1) the difficulty of measuring the surface tension exactly; and (2) the disturbances caused by changes in the surface of the molten metal. The following points will therefore be discussed briefly:—

(A) *Principles Underlying the Methods of Determining the Surface Tension.*[1 2 3]

(*a*) *Capillary Height Method.*—In this method a vertical capillary tube is immersed in the molten metal, and the difference in height between the metal in the capillary tube and the metal outside is measured. The method has hitherto been employed for metals by measuring the depression h in capillary tubes of graphite by electrical contact means or by radiography, the following formula being employed:—

$$A = \frac{h \times r \times \rho \times g}{2 \times \cos a}$$

where r is the radius of the capillary tube,
ρ the density of the molten metal, and
a the angle of contact.

Smith[3] has determined the surface tension of a certain number of metals by this method, on the assumption that the angle of contact was equal to 180 deg. He found:—

Sb	A = 274 dynes/cm.	Al	A = 520 dynes/cm.
Bi	346 ,,	Zn	707.5 ,,
Pb	424.5 ,,	Ag	858 ,,
Hg	447 ,,	Au	1,018 ,,
Sn	480 ,,	Cu	1,178 ,,

Libmann[4] also employed a modification of this method for studying the surface tension of copper and silver.

(*b*) *Method Employing the Detachment of Discs.*—In this method the force necessary to detach a disc from contact with the free surface of the liquid is measured. As far as the authors are aware, this method has not been employed for metals.

(*c*) *Weight of Drop Method.*—Tate in 1864 showed that if a vertical, sharp-edged tube is supplied with liquid, the weight of the drop is proportional to the weight of liquid which would be raised by surface tension in a tube of the same diameter.

Quincke[5 6] employed this method for determining the surface tension of molten metals by heating the ends of rings or wires to melting point and ascertaining the weight of the drops which formed and fell. He thus found that

$$a^2 = \frac{2A}{d} = 4.3 \quad \text{for Se}$$

4.3×2 ,, Hg, Pb, Ag, Bi, Sb
4.3×3 ,, Au
4.3×4 ,, Pt, Cd, Sn
(where d is the density) 4.3×6 ,, Pd, Zn, Fe
4.3×12 ,, Na
4.3×20 ,, K.

Matuyama[7] has also employed this method for determining the surface tension of antimony-cadmium, antimony-zinc, and antimony-lead alloys by measuring the weight of a drop falling from the orifice of a capillary tube and calculating the surface tension by Lohnstein's formula:—

$$P = 2\pi r.A.f\left(\frac{r}{A}\right)$$

where P is the weight of the drop,
r the radius of the base of the drop,
A the surface tension,
$f\left(\frac{r}{A}\right)$ a function of $\frac{r}{A}$.

(*d*) *Large Drop or Bubble Method.*—A large drop is placed on a horizontal plane surface. Assuming that the curvature of the intersection of the drop by a plane normal to the surface at a point, and hence normal to the meridian plane of the surface passing through that point, is negligible compared with that of the meridian section at the point considered (see Fig. 1), it appears that:—

$$A = \frac{h^2.d.g}{2}.$$

By employing this method, it is also possible to determine the characteristics of a drop formed by a liquid in a second liquid, provided that d is replaced by the differences in the densities of the two liquids. As will be shown later, use has been made of this property to determine the surface tension of aluminium in cryolite.[8]

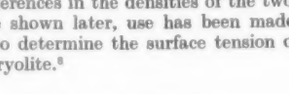

FIG. 1.—LARGE DROP.

Finally, in the case of a single liquid, it is possible to blow a bubble of air or inert gas in the liquid below a horizontal plane surface, and thus determine the surface tension of the liquid relatively to the gas. The authors have employed this method for determining the surface tension of unoxidised aluminium using a large bubble of argon.[8]

The properties of large drops were utilised by Siedentopf[9] for determining the surface tensions of Cd, Sn, Pb, Hg, Bi and Sn-Bi alloys, and also by Herzfeld[10] for Ni, Co and Fe.

(*e*) *Method Employing the Measurement of the Pressure Necessary to Force a Bubble or Drop Out of the End of a Capillary Tube.*—The pressure necessary to force a bubble of an inert gas through the end of a sharp-edged capillary tube immersed in a liquid is connected with the surface tension of that liquid by the following relationship, which was first deduced by Cantor and subsequently modified by Feustel:—

$$A = \frac{p.r}{2}\left(1 - \frac{2}{3}\frac{d.r}{p} - \frac{d^2.r^2}{p^2}\right)$$

where p is the pressure,
r is the radius of the capillary and
d is the density of the liquid.

Sauerwald and Drath[11] utilised this method for determining the surface tension of a large number of molten metals and alloys (Hg, Sn, Pb, Bi, Sb, Cu and Cu-Sb, Cu-Sn, Bi-Sn and Bi-Pb alloys).

Jaeger[12] and, later, Sauerwald[13] also employed the method for studying the surface tension of molten salts and slags.

Finally, Hogness[14] introduced a modification of the method by measuring the pressure necessary to cause a drop of a liquid to issue from the upper end of a vertical capillary tube, and in this way determined the surface tensions of Hg, Sn, Cd, Pb, Bi and Zn.

(*f*) *Other Methods.*—Mention should be made of the method of capillary waves employed by Grunmach[15] for determining the surface tension of molten metals (Pb), and the method employing the oscillations of a spherical drop, which are, however, of secondary interest.

To summarise, a certain number of experimental methods are available, and of these, the method utilising the properties of capillary tubes has been employed most. On the other hand, upon examining the results published by the various authors, it is found that the metals which have been most studied are low melting-point metals or are inoxidisable, and that on the whole the results are not very concordant. There are practically no data available for those metals which readily undergo changes when in the molten state, and with regard to aluminium in particular, it is scarcely possible to mention any investigations other than those carried out by Smith,[3] which will be discussed later.

Influence of the Cleanness of the Liquid on the Surface Tension

In the case of substances which are liquid at ordinary temperature, such as water and mercury, the exact measurement of the surface tension necessitates the use of absolutely clean substances, since according to the principle enumerated by Marangoni any accumulation of impurities on a portion of the surface diminishes the tension in that portion. Various methods of cleaning contaminated surfaces have been proposed for water and mercury.

In the case of molten metals, their surface tension may be disturbed either by the presence of impurities dissolved in the metal or by the formation of films due to reaction with the surrounding atmosphere.

Smith[16] gives an example of the first possibility in connection with the cupellation of silver. As the lead oxide is absorbed by the porous cupel, the silver tends to run together in the form of a bead under the action of its surface tension. If the silver contains a certain proportion of an element of low surface tension, such as tellurium, the metal spreads and disappears in the pores of the cupel instead of running together to form a bead.

A classical example of the second category is afforded by aluminium which cannot be melted, even in atmospheres where the partial pressure of oxygen is very low, without becoming covered with an elastic film of alumina.

Similarly, Vance White,[17] investigating the surface tension of lead alloys in an oxidising atmosphere, has shown in the case of a Linotype alloy containing an addition of 0.2 per cent. of zinc, that its tension may vary from 455 dynes/cm. in a reducing atmosphere to 1,198 dynes/cm. in the same atmosphere containing 50 per cent. of air. It follows from the foregoing that the measurement of the surface tension of molten metals should be carried out in such a manner as to avoid the formation of surface films by reaction with the surrounding atmosphere.

* Paper presented at the Annual Conference of the Institute of British Foundrymen in Glasgow.

Relations between the Surface Tension of Molten Metals and their Atomic Characteristics

In this field, among the oldest known relationships, mention should be made of that given by Eötvös[18] :—

$$A.V^{\frac{2}{3}} = k.(t_0 - t)$$

where A is the surface tension,
V the molecular volume,
t the temperature,
t_0 a temperature in the vicinity of the critical temperature, and
k a constant, independent of the liquid (of the order of 2.27),

and that derived from the preceding relationship by Ramsay and Shields[19] :

$$A.V^{\frac{2}{3}} = k.(\theta - t - d)$$

where θ is the critical temperature,
d a correction term in the vicinity of 6 (k being of the order of 2.12).

In the course of his researches on the surface tension of metals, Smith[3] discovered that the surface tensions are periodic functions of the atomic weights. When the curve of the reciprocals of the surface tensions $\frac{1}{A}$ for the different metals is plotted side by side with Lothar Meyer's curve showing the periodic rise and fall of the atomic volumes with increasing atomic weights, there is to be seen a general resemblance which is accentuated if the atomic volumes raised to the $\frac{2}{3}$ rd power are plotted as ordinates instead of the atomic volumes.

More recently, Sugden[20] has proposed the following relationship :

$$P = \frac{M.A^{\frac{1}{4}}}{D - d}$$

where M is the molecular volume,
D the density of the liquid and
d the density of the saturated vapour.

Sugden has termed the parameter P the *parachor*. The parachor has been determined for a certain number of metals. Later, use will be made by the authors of the calculated value of the parachor for aluminium, which is :

$$P_{Al} = 39.$$

Investigation of the Surface Properties of Oxidised and Unoxidised Aluminium[8]

The formation of a solid or liquid film of alumina by spontaneous or induced oxidation is of considerable practical importance on account of the chemical and mechanical properties of the film and its properties as an electrical insulator. This fact gives rise to disadvantageous consequences (difficulties in making contact between electrical conductors, difficulties in casting, etc.) or, on the other hand, useful results (protection against corrosion and oxidation, insulation of electrical windings, etc.). Although qualitative data at least are available regarding the thickness, porosity, insulating properties and the chemical resistance of this film, yet there are no such data available regarding the strength and the influence which the film exerts on the surface tension of the molten metal, although such data would be of prime importance both from the point of view of the protective action of the alumina and the casting properties of the aluminium.

The following is divided into two parts :—

(II*a*) Determination of the strength of the film of alumina.

(II*b*) Determination of the surface tension of oxidised and unoxidised aluminium.

(II*a*) Determination of the Strength of the Film of Alumina[8]

The method used was to determine the force required to rupture an aluminium wire melted in its sheath of alumina. Two different modifications of this method were employed :—

(*a*) *Wire Suspended by One End.*—An aluminium wire is suspended vertically by its upper end and a source of heat—for instance, the flame of a bunsen burner—is passed in a uniform manner upwardly along the wire, which melts over a certain length but retains its original shape, due to the tube of alumina acting as a sheath. This tube breaks at the instant the weight of metal which it is supporting exceeds the strength of the envelope of alumina. Knowing the diameter of the wire and the load supported by the tube of alumina, this load being determined by weighing the portion of wire which drops off, it is a simple matter to find the strength of the oxide film per unit length.

Experiments were made on wires of 0·5 mm., 1 mm., 2 mm. and 2·5 mm. in diameter. Fig. 2 shows the variation of the load supported by the annular film of alumina with the diameter of the film. From these experiments it is deduced that the mean strength of the film of alumina is :

$$R_1 = 0{\cdot}20 \text{ gram/mm.} = 1{,}960 \text{ dynes/cm.}$$

(*b*) *Wire Suspended by Both Ends.*—An aluminium wire is suspended by both ends, employing a device which allows it to assume freely its position of equilibrium in a vertical plane. An electric current is passed through the wire to heat it by Joule effect, and when it is melted in its sheath of alumina it assumes the form of a catenary. Knowing the span of this catenary and its sag at the instant of rupture, it is possible to calculate the force supported by the tube of alumina at the point of its rupture.

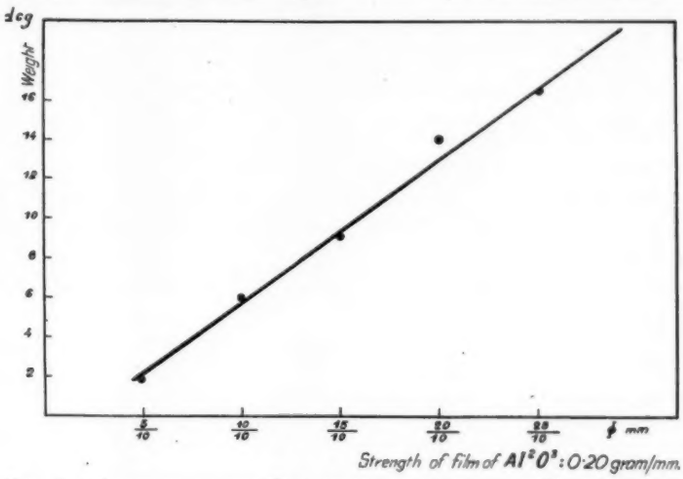

FIG. 2.—VARIATION OF THE STRENGTH OF AN ALUMINIUM TUBE WITH THE DIAMETER OF THE ALUMINIUM WIRE.

Experimental Apparatus

As shown in Fig. 3, the aluminium wire was fixed at each end to the centre of a rod connecting two cylindrical sheet-metal floats f placed respectively in two dishes filled with mercury. To prevent the floats from rubbing against the sides of the dishes when pulled by the weight of the aluminium wire, the rods connecting the pairs of floats f were held in position by wire loops a, which, however, allowed them to rotate freely about their axis of rotation without appreciable friction.

The dishes of mercury also served for the connection of the leads carrying the current for fusing the aluminium wire. As the wire becomes hotter, it expands, melts and assumes the shape of a catenary, the sag of which can be measured by means of a squared board t set up vertically just behind the wire. The fusion of the aluminium wire is ascertained by moving the latter carefully by means of a magnet. By gradually increasing the span of the catenary, a moment is reached when it breaks at one of its ends.

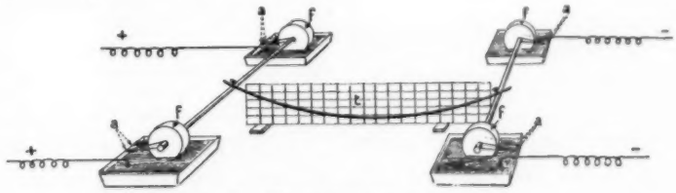

FIG. 3.—EXPERIMENTAL LAY-OUT.

Calculation of the Load Supported by the Tube of Alumina at the Point of Rupture

Considering a perfectly flexible wire suspended at two points in the same horizontal plane, an element of wire of length ds weighs

$$k.ds = \pi.r^2.d.g.ds$$

where r is the radius of the wire,
d is the density of the aluminium,
g is the acceleration due to gravity.

If T is the tension of the wire at the point (x, y), there are the following equations for equilibrium :—

$$d\left(T\frac{dy}{ds}\right) = \pi.r^2.d.g.ds$$

$$d\left(T\frac{dx}{ds}\right) = 0$$

which gives by integration :

$$y = \frac{a}{2}\left(e^{\frac{x}{a}} + e^{-\frac{x}{a}}\right) \text{(catenary)} \qquad (1)$$

$$T = k.a.\frac{ds}{dx} = k.\frac{a}{2}.\left(e^{\frac{x}{a}} + e^{-\frac{x}{a}}\right) = k.y \qquad (2)$$

a being an integration constant.

The equation (1) is obtained by referring the catenary to its *axis of symmetry* and to its *base*. The general equation of the equilibrium curve is :

$$y - y_0 = \frac{a}{2}.\left(e^{\frac{x-x_0}{a}} + e^{-\frac{x-x_0}{a}}\right)$$

Taking as the point of origin one of the ends of the catenary and defining the latter by its length and the distance between the supports, let

l = the length of the arc of the catenary,
a = the distance between the points of attachment.

The catenary passes through A and through B ; therefore :

$$-y_0 = \frac{a}{2}\left(e^{-\frac{x_0}{a}} + e^{\frac{x_0}{a}}\right)$$

$$-y_0 = \frac{a}{2}\left(e^{\frac{a-x_0}{a}} + e^{-\frac{a-x_0}{a}}\right)$$

Furthermore, the length of the catenary is given by*

$$l = a\left(\frac{a}{e^{\frac{a}{2a}}} + e^{-\frac{a}{2a}}\right)$$

If we put

$$\frac{a}{2a} = u, \text{ we may write: } \frac{l}{a} = \frac{e^u + e^{-u}}{2u}$$

which can be developed into an entire series in the following manner:—

$$\frac{l}{a} = 1 + \frac{u^2}{1.2.3} + \frac{u^4}{5!} + \ldots + \frac{u^{2n}}{(2n+1)!} \ldots$$

whence, by limiting the development to its third term:

$$\frac{u^4}{5!} + \frac{u^2}{3!} + \left(1 - \frac{l}{a}\right) = 0.$$

By means of this fourth-power equation it is possible to calculate $u = \frac{a}{2a}$, and consequently a. Knowing u, it is easy to calculate a, x_0, y_0, and hence the tension of the catenary at the point of maximum load, that is to say, at A or at B.

A certain number of experiments were made on wires of 0.5 and 1 mm. in diameter. One of these experiments, for example, carried out on wire of 0.5 mm. in diameter, gave:—

l_0 (initial length of the catenary at the temperature of the surroundings) = 39.5 cm.

l (length of the catenary at the melting point of the aluminium) = 40.2 cm.

a (distance between the points of suspension) = 38 cm.

f (sag of the catenary at the moment of its rupture) = 7.3 cm.;

thus, the value of the strength of the film of alumina per millimetre of length was

$$T = 0.24 \text{ gr./mm.}$$

The mean of the results obtained by the catenary method gives

$$T_{mean} = 0.20 \text{ gr./mm.}$$

a value in agreement with that given by the vertical wire method.

Measurements of the thickness of the film of alumina[21] were made by the method given by H. Sutton by reducing the aluminium in a current of dry chlorine at a high temperature and weighing the residual alumina. The experiments gave for the mean thickness of this film of alumina formed by heating about 1 min. at about 700 deg. C.:

$$e_{mean} = 10^{-5} \text{ cm.} = 0.01\,\mu$$

which gives

$$R_2 = 2 \text{ kg./mm.}^2$$

for the tensile strength of the alumina.

It will thus be appreciated that this mechanical strength is much greater than that which could have been expected according to the results obtained on crystallised alumina.[22]

(IIb) Determination of the Surface Tension of Oxidised and Unoxidised Molten Aluminium[3]

In this investigation it was proposed to determine the surface tension of aluminium free from any oxidation and to compare the value obtained with that obtained with aluminium covered with its film of alumina.

(*a*) *Surface Tension of Aluminium covered with a Resilient Film of Alumina.*—If large drops of aluminium are made in the air, they are immediately covered with a film of alumina. By determining the elements of large drops thus formed and solidified, the following mean values are found:

$$e = 12 \text{ mm.}$$
$$h = 8.5 \text{ mm.}$$

which gives

$$A = \frac{1}{2} \times \overline{0.85}^2 \times 2.38 \times 981 = 840 \text{ dynes/cm.}$$

(*b*) *Surface Tension of Aluminium Free from Oxidation.*—Owing to the very low tension of dissociation of alumina, it is extremely difficult to measure the real surface tension of unoxidised aluminium. This explains the scarcity of information regarding the surface tension of aluminium and the doubtful character of the values which have been given.

For these determinations two methods based on the properties of large drops were used.

(*α*) *Formation of a Bubble of Argon in the Interior of the Molten Aluminium*

Method.—Aluminium of 99.5 per cent. purity is melted in a moderately deep graphite crucible (Fig. 4). A bubble of pure and dry argon is injected into the metal by means of a bent tube below a horizontal plane P consisting of a thin steel plate having a slight downwardly directed concavity. A large bubble of argon is thus produced under the plane P, and the elements of the bubble may be measured by sawing the aluminium ingot, after solidification, along a meridian plane.

The first experiments were disturbed by pipe formation on the solidification of the metal. In order to obtain, after solidification, a bubble which is not deformed and is of the correct measurements, care must be taken to employ a device P of low thermal inertia (this being effected by using a thin steel plate)

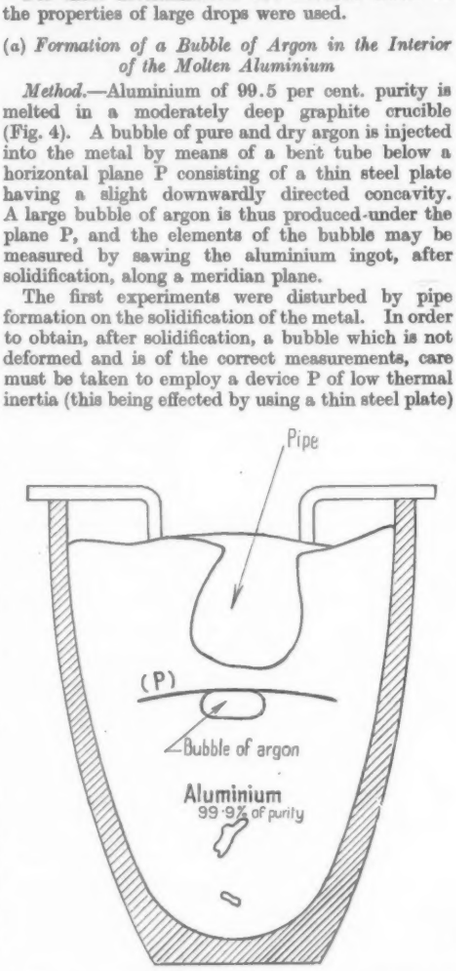

FIG. 4.—BUBBLE OF ARGON IN ALUMINIUM.

and immersed to a sufficient depth in the bath of aluminium for the bubble to form below the region of pipe formation of the ingot. This method gave us as a mean:

$$A = 300 \text{ dynes/cm.}$$

(*β*) *Investigation of the Equilibrium Aluminium-Cryolite-Air*

Preliminary measurements were made with a view to determining the surface tension A_1 of aluminium in cryolite and A_2 of cryolite in air, making use of the properties of large drops.

Surface Tension of Aluminium in Cryolite

It is an easy matter to produce large drops of aluminium in molten cryolite without the formation of a film of alumina on the surface of the liquid metal, since the cryolite dissolves the alumina. After the whole has solidified, the elements of the drop are determined on a meridian section of the ingot. We found:

$$e = 28.5 \text{ mm.}$$
$$h = 19.0 \text{ mm.}$$

Taking for the densities of aluminium[23] and cryolite[24] at 975 deg. C., the temperature of solidification of the cryolite,

$$d_{Al} = 2.295$$
$$d_{cryolite} = 2.20$$

it is deduced therefrom:

$$A_1 = \frac{1}{2} \times \overline{1.90}^2 \times (2.295 - 2.20) \times 981 = 170 \text{ dynes/cm.}$$

Surface Tension of Cryolite in Air.—This was determined by injecting dry air through a bent tube into molten cryolite so as to form a bubble under a horizontal plane constituted by a steel plate having a slight downwardly directed concavity. It was found:

$$e = 7 \text{ mm.}$$
$$h = 4.8 \text{ mm.}$$

Taking as densities at 975 deg. C.:

$$d_{cryolite} = 2.20$$
$$d_{air} = \text{negligible compared to } d_{cryolite}$$

it is found:

$$A_2 = \frac{1}{2} \times \overline{0.48}^2 \times 2.20 \times 981 = 250 \text{ dynes/cm.}$$

Surface Tension of Aluminium in Air.—It is now proposed to consider the *hypothetical case** of a lens of cryolite floating on the surface of a bath of unoxidised aluminium (Fig. 5). Let M and N be two points situated on the same vertical line, the former being placed on the surface of separation cryolite-air and the latter on the surface of separation aluminium-cryolite. Let

p be the pressure in the air and p_2 the pressure in the cryolite } in the proximity of M
p_1 the pressure in the cryolite and p' the pressure in the aluminium } in the proximity of N.

Applying the laws of hydrostatics, we may write:

(1) $p' = p + y_1.D.g$
(2) $p_1 = p_2 + (y_1 + y_2).d.g$

where D is the density of the aluminium, d is the density of the cryolite.

Since the lens of cryolite is in equilibrium, it may be supposed to be solidified and may be considered

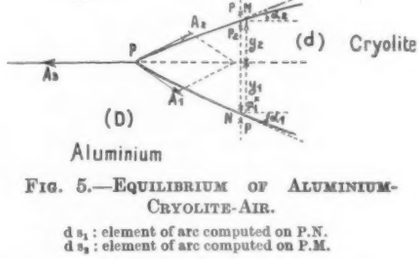

FIG. 5.—EQUILIBRIUM OF ALUMINIUM-CRYOLITE-AIR.

$d s_1$: element of arc computed on P.N.
$d s_2$: element of arc computed on P.M.

as a float in equilibrium on the surface of the molten aluminium. The external forces applied to it are gravity, the thrust of the displaced metal, and finally, the forces of surface tension, which latter forces form a system in equilibrium at each point of contact of the three media. We thus have:

$$y_1.(D-d) = y_2.d.$$

From the combination of the equations (1), (2) and (3), we deduce:

$$p_2 - p = p_1 - p'$$

or:

$$(4) \qquad \frac{A_2}{R_2} = \frac{A_1}{R_1}$$

A_2, R_2 and A_1, R_1 being respectively the surface tensions and the radii of curvature in the meridian plane of the lens at M and N.

The notations of Fig. 5 give:

$$R_2 = \frac{ds_2}{da_2} = \frac{dy_2}{\sin a_2.da_2}$$
$$R_1 = \frac{ds_1}{da_1} = \frac{dy_1}{\sin a_1.da_1}$$

which allows one to write (4) as follows:—

$$(5) \quad A_2.\frac{\sin a_2.da_2}{dy_2} = A_1.\frac{\sin a_1.da_1}{dy_1}$$

Since the equation (3) when differentiated gives:

$$dy_1.(D-d) = dy_2.d,$$

(5) may be written:

$$A_2.d.\sin a_2.da_2 = A_1.(D-d).\sin a_1.da_1$$

which by integration becomes:

$$A_2.d.\cos a_2 = A_1.(D-d).\cos a_1 + C \qquad C = \text{constant.}$$

* The authors have refrained from giving here the intermediate steps in the calculation. The reader interested in the question is invited to refer to P. Appel: "Traité de Mécanique rationnelle," Vol. I, p. 198 (Gauthier Villars et Cie, 1926 edition).

* Such an experiment could not be made actually, because the exposed surface of the aluminium would oxidise at once on contact with the air

The lens of cryolite is a solid of revolution by reasons of symmetry, and on the vertical line of its poles we have :

$A_2.d = A_1.(D-d) + C$ or $C = (A_2 + A_1).d - A_1.D$

Let us consider the point P on the line of contact of the three media aluminium, cryolite, air. At P we have simultaneously :

$$\frac{\sin a_1}{A_1} = \frac{\sin a_2}{A_2} = \frac{\sin (a_1 + a_2)}{A_3} \quad .. \quad .. \quad .. \quad (6)$$

$$A_2.d.\cos a_2 - A_1.(D-d).\cos a_1 = (A_2 + A_1)d - A_1.D \quad (7)$$

a system of three equations which enable us to calculate a_1, a_2 and A_3, knowing A_1 and A_2.

Application to the System Aluminium-Cryolite-Air.—

Putting $\begin{cases} \cos a_2 = x \\ \cos a_1 = y \end{cases}$

the first relationship (6) and the equation (7) are written :

$$\begin{cases} A_2^2.x^2 - A_1^2.y^2 = A_2^2 - A_1^2 \\ A_2.d.x - A_1(D-d).y = A_2.d - A_1.(D-d) \end{cases}$$

or :

$$A_2.d(x-1) - A_1.(D-d).(y-1) = 0 \quad (8)$$

$$A_2^2.(x^2-1) - A_1^2.(y^2-1=0) \quad .. \quad (9)$$

The solutions of the problem are thus furnished by points of intersection of the straight line of equation (8) with the hyperbola of equation (9), this straight line and hyperbola already having in common the point $x = 1$, $y = 1$.

In the case of the equilibrium with which we are now dealing,

$A_1 = 170$; $A_2 = 250$; $d = 2.20$; $D = 2.29$.

Consequently, the equation of the straight line (8) becomes

$$550x - 15.3y - 535.7 = 0$$

which is the equation of a straight line having a very large angular coefficient, situated as indicated in

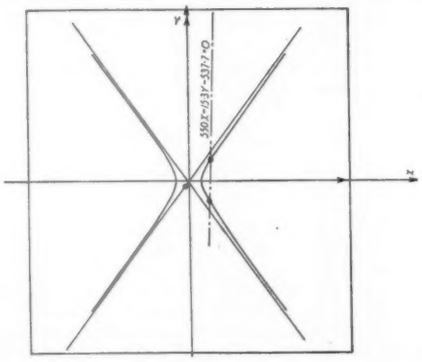

FIG. 6.

Fig. 6, and consequently intersecting the hyperbola such that :

$$/x/\simeq 1, \ /y/\simeq 1$$

or

$$a_1 = a_2 = \epsilon,$$

ϵ being a very small value.

Interpretation.—The result $a_1 = a_2 = \epsilon$ shows that the lens of cryolite is extremely thin (Fig. 7) and that, consequently, we have substantially :

$$\vec{A}_3 = \vec{A}_1 + \vec{A}_2 = 170 + 250 = 420 \text{ dynes/cm.}$$

This value, moreover, constitutes an upper limit of the surface tension of unoxidised aluminium, since if the angle between the tensions A_1 and A_2 is not zero, their resultant is such that

$$\vec{A}_3 < \vec{A}_1 + \vec{A}_2$$

It follows from these experiments that the surface tension of oxidised aluminium (840 dynes/cm.) is twice as great as that of unoxidised aluminium, which lies between 300 and 420 dynes/cm. This emphasises the importance of the films of alumina and explains the difficulties met with in aluminium foundry practice.

Smith[3] in an investigation to which reference has already been made determined the tension of aluminium by the capillary-tube method, and found :

$$A = 520 \text{ dynes/cm.}$$

which may be explained by the fact that he took precautions to avoid the oxidation of the aluminium either by passing a steady current of illuminating gas through his furnace or by allowing wood charcoal to float on the surface of the metal—methods which are insufficient to prevent completely the oxidation of the aluminium.

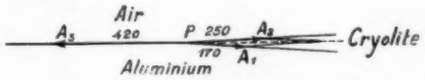

FIG. 7.—EQUILIBRIUM ALUMINIUM-CRYOLITE-AIR.

If $300 \leqslant A_{Al} < 420$ dynes/cm., itf ollows that the *parachor* of this metal (see above) is of the order of :

$$P = 46$$

a value which agrees satisfactorily with the calculated value :

$$P_{calc.} = 39.$$

In conclusion, it should be pointed out that the equilibrium alumina-cryolite-air is impossible, since

$$840 > 170 + 250$$

which explains why cryolite spreads instantly on the oxidised surface of baths of aluminium.

III.—Influence of the Surface Tension on "Life"

Most of the authors who have considered "life" have seen *a priori*, which, moreover, appeared logical, a preponderant influence of two well-defined physical properties, the surface tension and fluidity. Actually, personal experiments have shown that these two physical factors are of only secondary importance, at least provided the metal is not altered chemically and that, on the contrary, the phenomena of solidification are of primary importance.

The authors have, in fact, shown that :—

(1) *For pure metals*[25, 26] the "life," measured by the length Λ attained by a horizontal flat spiral, is expressed by :

$$\Lambda = A_0 d \frac{c(\Theta - F) + L}{F - \theta}$$

where Θ is the pouring temperature,
θ is the temperature of the mould,
F is the temperature of solidification of the metal,
c is the specific heat
L is the latent heat of fusion } of the metal.
d is the density
A_0 is a constant

It follows that the "life" of pure metals is the resultant of complex factors, amongst which the calorific properties (F, L, c) play a part of primary importance.

(2) *For alloys*[27, 28, 29, 26] the following laws have been established :—

(*a*) "Life" varies inversely with the solidification range and exhibits a relative maximum when fusion is congruent (pure metals, eutectics, definite compounds) and a minimum for saturated solid solutions. In this solidification range the first stage (crystals not in contact) has the greatest effect.

(*b*) "Life" depends upon the faces of solidification and is relatively much greater when the liquid gives rise to convex crystals (definite compounds) than when it gives dendrites (solid solutions approximating to pure metals). This is connected with the part played by the first stage of solidification. This shows once again the primary importance of the factors of solidification and crystallisation in the castability of alloys.

Furthermore, after reflection, it is not possible to see clearly what relationships there may be between the surface tension, a factor pertaining to the liquid state, and the equilibrium diagram, which, on the contrary, defines the phenomena occurring when the solid phase appears. The surface tension could only be influenced by the constitution as defined by the diagram if such constitution persisted in the liquid phase in the form of undissociated compounds, which, moreover, does take place in certain cases.

If the surface tension only plays a secondary part in the "life" as defined by the length of flow of the metal before solidification in a spiral of appreciable section, this is no longer the case when the metal has to penetrate passages of small cross-section.

Consider, in fact, a tank supplying liquid under a head to a horizontal passage (Fig. 8), and suppose that the liquid does not wet the passage. The liquid has entered the passage, and by hypothesis the whole is in equilibrium. Let

p_0, p_1, p_2, p'_2 be the pressures at the points marked in Fig. 8,
a, the angle of contact of the liquid in the passage,
d, the density of the liquid,
r, the radius of the capillary tube.

We have :

$$p'_2 = p_2 \qquad p_0 = p_1 \qquad p_2 = p_0 + h.d.g$$

$$p'_2 - p_0 = \frac{2A}{R} = \frac{2A \cos a}{r}$$

whence,

$$h.d.g. = \frac{2A \cos a}{r}$$

$h.d.g$ is the head above which the liquid can enter and flow through the passage. In other words, in the phenomena of "life" the effect of the surface tension is to diminish the metallostatic head by the quantity $\frac{2A \cos a}{r}$, which, although negligible in the case of passages of normal dimensions, becomes very appreciable when the metal has to pass through fine orifices.

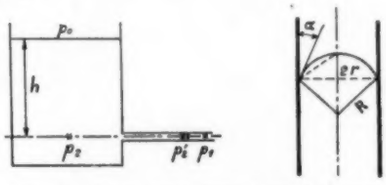

FIG. 8.—TANK SUPPLYING LIQUID UNDER PRESSURE TO A HORIZONTAL PASSAGE.

Considering the case of mercury and a capillary tube of glass :

$A = 418$ dynes/cm., $a \simeq 45°$,* $d = 13.6$ c.g.s. ; $g = 981$

whence

$$h = \frac{0.044}{r}$$

Consequently, if

$$r = \frac{1}{100} \text{ mm.},$$

a head of 44 cm. of mercury will be required to cause the metal to enter the capillary.

It will thus be appreciated that the surface tension may play an important part in the accurate casting of parts comprising fine details, such as, for instance, the characters employed in Linotype printing.

"Searching" and Capillarity

"Searching" is the penetration of the metal into the wall of the mould or cores. It is met with chiefly in the case of cores in copper founding. This penetration takes place :—

(*a*) Through the pores of the sand if the walls have not been coated with a protective dressing, in which case the penetration depends upon the *permeability* of the sand (varying with the sand, its moisture content and ramming density). The result is a metallic sponge or scab, which adheres to the casting and, at the least, appears in the form of incrustations of sand on the surface of the casting.

(*b*) Through fissures in the dressing, if the walls have been coated with a protective dressing. The

* The values indicated for a by the various authors are somewhat discordant. The authors have adopted a mean value which also corresponds to that given by Gay-Lussac.

production of these fissures depends upon the thermal properties of the sand (expansibility, conductivity, specific heat), its preparation (moisture, dryness, shrinking) and the method of applying the dressing and its nature. The result is the formation of thin metallic projections or partitions terminating in the above-mentioned scab.

In all cases, the penetration of the metal into the pores and fissures depends upon the "life," the pressure and capillarity on account of the fineness of the cavities.

Ignoring the factors which depend upon the mould, the casting and the dressing, and confining our attention to the phenomena which depend upon the metal, viz., "life" and capillarity, these involve the following factors :—

(1) *For the "Life."*—The pouring temperatnre; the nature of the metal or alloy; the temperature of the mould (in this case of the walls, and consequently the rate of heating of these walls).

This last factor depends not only upon the nature of the walls of the mould (especially the moisture content and the thermal properties of the sand), but also upon the weight and shape of the casting and the situation of the wall relatively to it. In particular, there is a very distinct difference between the

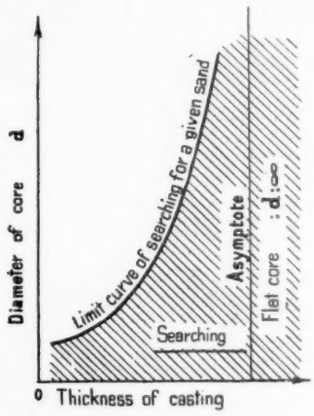

FIG. 9.—RELATIONSHIP BETWEEN LIMIT OF SEARCHING, THICKNESS OF CASTING AND CORE DIAMETER.

mould and cores, since the mould surrounds the casting and has a greater mean radius of curvature than the core, which is surrounded by the molten metal. Thus, "searching" is to be considered, above all, in connection with the cores, and depends upon their diameter d and the thickness e of the metal, as shown in Fig. 9.*

In particular, when the temperature of the sand attains the temperature Θ of the metal, the fluidity is involved. This is the limit case of castability.

(2) *For the Capillarity.*—In addition to all the factors previously discussed, the phenomena of capillarity involve the thickness ϵ of the cavities, pores of the sand or fissures of the dressing, the surface tension of the molten metal and the wetting of the walls by the metal, which depend upon the *state of the surfaces* of the metal and walls.

In the case of a liquid which does not wet the walls (which is the general case of molten metals in refractory moulds), we have shown that the influence of the surface tension appears in the form of an additional pressure equal to $\frac{2A\cos a}{r}$ which is necessary to cause the molten metal to penetrate a horizontal capillary conduit of diameter $2r$.

If, on the contrary, the liquid wets the walls, it is drawn into the capillary passage, and if the latter is horizontal, the liquid will flow through indefinitely.

* In experiments on bronze bushes, A. Miroux (Bull. A.T.F., October 1928, p. 295) confirmed that "searching" took place when the diameter of the core and the thickness of the bush exceeded certain values (15 mm. and 12.5 mm. for the experimental conditions selected), all the other factors remaining constant, and he plotted the corresponding curves.

The cavities in sand moulds are necessarily irregular and comprise successive enlargements and constrictions, and hence the phenomena of capillarity are complicated by these variations in diameter. It is, indeed, well known that the resistance to the movement of drops of liquid in capillary tubes possessing successive constrictions and enlargements differs considerably, according to whether or not the liquid wets the walls, and if the liquid does wet the walls, according to whether or not air bubbles are included in the liquid. In fact, in the last-mentioned case the resistance is considerable for the introduction of air and is very slight for the penetration of the liquid.

Hence, there are two very distinct cases, depending on whether or not the molten metal wets the walls. Thus, as shown in Fig. 10, a drop of liquid on the horizontal surface of the solid assumes the shape I or II, according to the circumstances, and the *angle of contact* a or the liquid angle formed by the tangent to the edge of the drop and the solid surface is given by :

$$\cos a = \frac{T_{AS} - T_{LS}}{T_{AL}},$$

T_{AS}, T_{LS}, T_{AL} being the three measurable or unknown surface tensions at the three surfaces of contact or separation of the air A, the solid S and the liquid metal L. This relationship, expressing the conditions for the equilibrium of the three tensions, leads to the statement that :

when $\cos a < 0$, a obtuse, the liquid does not wet ;
,, $\cos a > 0$, acute, the liquid wets.

In the special case when $\cos a = 1$, $a = 0$, the liquid spreads indefinitely in the form of a film over the solid and wets the solid perfectly.

Since the angle of contact depends solely upon the nature of the liquid and of the solid, it is constant irrespective of the inclination of the surface, and for a vertical wall the surface of the liquid at the point of contact is *convex if the liquid does not wet and concave if the liquid wets.*

This, however, is much more a mathematical mode of expression rather than an explanation which would enable one to foresee whether or not the liquid will wet, because even if one does not always know T_{AL} and T_{LS}, one is ignorant of the value and significance of T_{AS}.

In everyday language, this means that when the liquid-solid attraction prevails, the liquid wets. When, on the other hand, the mutual attraction of the particles (atoms, ions, molecules) of the liquid prevails, the liquid does not wet.

The attraction of the particles or the cohesion manifests itself in liquid in the "internal pressure" and in solids in the "intrinsic pressure" or hardness. These magnitudes are, indeed, related to the surface tension (T. W. Richards, Traube, Sydney Smith), which, according to T. W. Richards, is likewise related to the chemical affinity.

Liquids are more soluble in one another the more nearly alike are their respective internal pressures, and investigations on the intermiscibility of organic liquids, and also of solid solutions of metals, have shown the importance of the ratios of the atomic volumes and the concentrations of valency electrons. The atomic characteristics and valencies thus play a fundamental part in intermiscibility and internal pressure.

Thus, in the case of ionic valencies, the internal pressures are greater the more strongly polar are the molecules and the greater are the forces of affinity. Strongly polar compounds do not dissolve in water which is a polar liquid, but the molecules

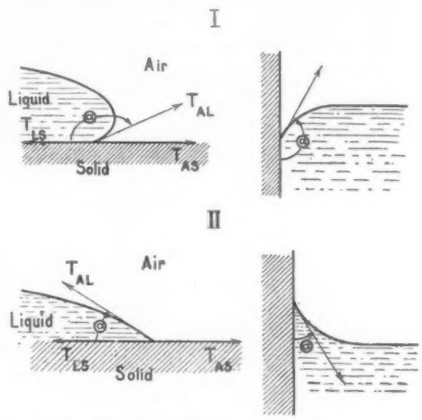

FIG. 10.—INFLUENCE OF WETTING ON CAPILLARITY.

retain a sufficient affinity for those of water to be readily wetted. At the same time, there is an increase in the hardness and a rise in the melting point. Thus, in the increasing order of internal pressures and affinity, wetting precedes solution or combination.

On the other hand, the solid-liquid attraction manifests itself not only by the crystalline orientation of the electrolytic deposit on the crystals of the supporting metal, *when nothing alters the perfect contact*, but also by the molecular orientation of the liquid, which, in a manner, proceeds towards the pre-ordained state, that is to say, the crystallised state. Thus, oils which wet metals exhibit at the contact an oriented molecular layer or film, the consideration of which is of fundamental importance from the point of view of lubrication.

In this connection, it is likewise opportune to recall the formation of mono- or bimolecular layers of fatty substances on metal surfaces. These phenomena have been investigated by J. J. Trillat by means of electronic diagrams which show the formation and propagation of films of grease on metal surfaces, unless extremely minute precautions are taken in preserving them.

It thus appears possible, by considering the atomic magnitudes and affinities which control miscibility, the ability to combine and the molecular orientation, to shed some light on the phenomena of wetting related to them, and considerable importance is to be attached to the physical or chemical surface changes.

To return to the subject now under discussion, if a molten metal in contact with a mould of silicious sand is studied, there is complete insolubility between

(*Concluded on page* 34.)

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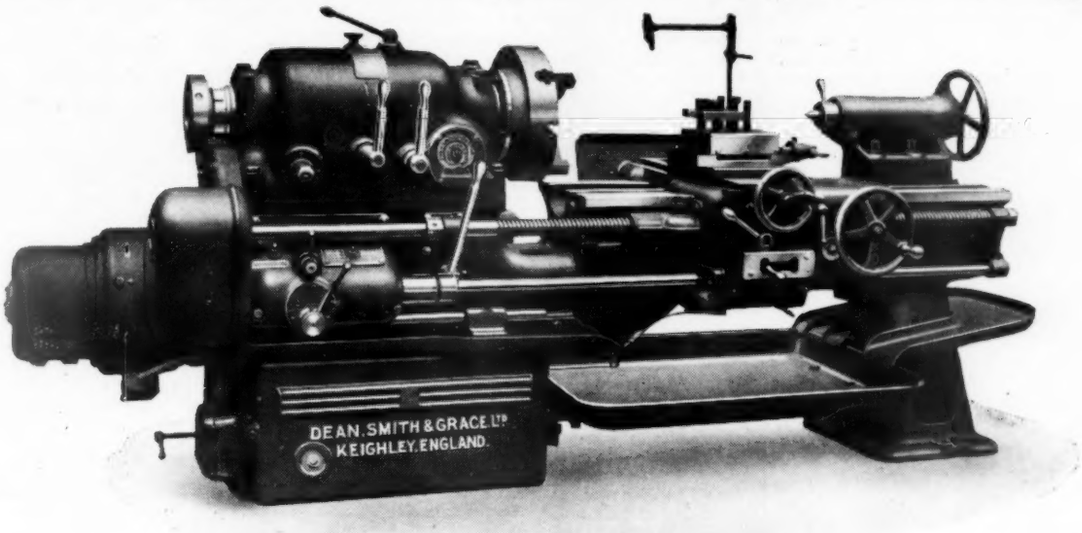
For Heavy Engineering Castings



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The Stanton Ironworks Company Limited, Near Nottingham

The Week's News in Brief

Trade Talk

MEMBERS OF THE Keighley Association of Engineers are to visit the Britannia Works of Hopkinsons, Limited, Huddersfield, on Saturday.

AN IMPORTANT EXTENSION to the foundry of the General Electric Company at Witton, Birmingham, has just been completed. The switchgear works also have been considerably enlarged.

ABOUT 30 MEMBERS of the Sheffield Society of Engineers and Metallurgists visited Liverpool on July 1 to inspect the ventilating and control stations of the Mersey Tunnel, and to tour the Mersey docks.

A REAL SERVICE to students of refractory materials has been effected by the publication of a classified list of articles which have appeared in the "Refractories Journal" since its inception in September, 1925, to December, 1934, together with an authors' index.

AFTER BEING CLOSED for 12 years the Egglescliffe Foundry, Stockton, belonging to Head, Wrightson & Company, Limited, of Thornaby, will shortly be reopened because of pressure of orders. The foundry will be used for the production of heavy iron castings and will employ about 100 men.

CONSTRUCTION has commenced of the new Jugoslav iron and steel works at Zenice in Bosnia. These works, which are being built by Krupps at an estimated cost of £636,000 (at current rates), will, it is expected, make Jugoslavia independent of foreign imports of iron and steel, of which nearly £1,000,000 in value is imported annually.

ARISING OUT OF clearing agreements between Belgium and Germany, Hungary, Roumania, Greece and Spain, certain goods, when imported into Belgium and Luxemburg from the United Kingdom, must be accompanied by a certificate of origin. These goods include ores, coal and manufactures of iron, steel and malleable cast iron.

A LARGE FACTORY at Tyseley, Birmingham, having a floor space of 250,000 sq. ft., and covering a site area of 14 acres, has been purchased by the Midland Electric Manufacturing Company, Limited, for the production of electrical switchgear, motor controls and other apparatus. The present works in Barford Street are now quite inadequate to cope with the demands for the firm's products. The change-over will take some considerable time, and the new factory will not be in full production for about twelve months. A new foundry is to be built, as well as a pottery—stated to be the only one in Birmingham—where the company will manufacture the porcelain used for insulators.

ARRANGEMENTS HAVE BEEN CONCLUDED whereby Colvilles, Limited, of Glasgow, will acquire control of the Lanarkshire Steel Company, Limited, of Motherwell. This is a further step in the rationalisation of the Scottish iron and steel industries, which has proceeded steadily in recent years. The Lanarkshire Steel Company, the works and headquarters of which are at Flemington, was incorporated in 1897 to take over the business of a company of similar name, then in liquidation. The authorised capital is now £475,000, and the issued capital £460,000. Colvilles, Limited, the acquiring company, at present has an authorised capital of £6,000,000, of which £5,789,550 is issued.

A NEW INDUSTRIAL ESTATE near Manchester, to be called the Barton Estate, is to be developed in a similar way to Trafford Park, which it adjoins. Covering 1,000 acres, it will have a frontage of more than three miles on the Manchester Ship Canal, and will be connected by rail with the Manchester dock warehouses, transit sheds and berths, and main-line railways. The Manchester Ship Canal Company, which owns the estate, proposes to construct two new railways on the site, and facilities will be available to manufacturers for the construction of private wharves with side basins or lay-byes. The project has been brought into prominence by the Manchester Ship Canal Company Bill, which has been approved for third reading by a Select Committee of the House of Lords. The necessary powers for the construction of the new railways are expected to be obtained during the present session of Parliament, after which it is understood operations will begin immediately.

MATTHEW SWAIN, LIMITED, of Newton Heath, Manchester, last week celebrated its diamond jubilee at a dinner held at the Grand Hotel, Manchester, at which nearly seventy members of the staff were present. The firm was founded by Matthew Swain in 1876, following the closing down of the Railway Steel & Plant Company, the largest manufacturing concern in Newton Heath, where he had been in charge of the iron and steel moulding department. In 1900 the business was incorporated as a private limited company, the family retaining the shares, thus continuing the long personal association of which the present directorate is so proud. The first directors were Matthew Swain (chairman) and his two sons, Josiah and John. Continuous progress was made, though in 1903 the company suffered a severe loss by the death of its chairman. He was succeeded by Mr. John Swain, and Mr. James V. Fawbert, who had served the company since 1898, was appointed secretary in 1910. To-day the works cover four acres and employ between 400 and 600 workpeople.

Capillarity as a Factor in Foundry Practice

(Continued from page 32.)

the liquid with metallic affinities and the solid silica with energy affinities of co-valency. There is therefore no wetting, but if there is oxidation of the surface of the metal by the formation of a film of oxide, even very thin, it is necessary to distinguish :—

(*a*) Oxides which, although they readily form silicates that are insoluble in the molten metals, possess a metallic character, such as oxides of iron, nickel, cobalt and copper, and which consequently possess a certain solubility in the metal. In this case, wetting may take place.

(*b*) Oxides of polyvalent metals, such as alumina, which, like silica, possess atomic valency bonds and are insoluble in the metal, form on the surface a film whose strength and influence on the surface tension have been discussed in the foregoing.

This film opposes wetting, and hence "searching," and for that reason, even relatively small additions of aluminium may be made in order to modify considerably the surface property of molten alloys. Such films also exert their influence during the re-melting of scrap.

NOTE.—Another defect in casting which is connected to these phenomena is the formation of "chilled drops" produced by the spurting of the molten metal cast into the mould from the top. These drops may adhere to the walls and afterwards may not be incorporated in the metal when the level of the molten metal reaches them. This adhesion and incorporation are dependent upon the same factors as those which have been discussed in the foregoing.

Contracts Open

Bagdad, August 4.—Cast or spun-iron spigot and socket pipes, for the Bagdad District Water Board. The Department of Overseas Trade. (Reference T.Y. 30,399.)

Hartlington, July 15.—1,800 yds. of 3-in. cast-iron pipes and 2,000 yds. of 2-in. galvanised pipes, for the Skipton Rural District Council. Mr. A. Rodwell, engineer, Granville Street, Skipton. (Fee £2 2s., returnable.)

Hindley, July 14.—Cast-iron mains and specials, for the Gas and Water Department. The Engineer and Manager, Gasworks, Hindley.

North Kesteven, July 20.—Spun-iron socketed pipes, special castings, etc., for the Rural District Council. Mr. J. Chadwick, 25, Clasketgate, Lincoln, surveyor to the Council. (Fee £3 3s., returnable.)

Parkham, July 20.—Pump, capable of delivering water, from a 9-in. borehole 100 ft. deep, at the rate of 5,000 galls. per hr., for the Northam Urban District Council. Mr. A. E. Parry, water engineer, Council Offices, Northam.

Personal

SIR ROBERT HADFIELD has been elected an honorary member of the Société de l'Industrie Minérale, St. Etienne.

MR. P. H. DURRANS, a director of J. Durrans & Sons, Limited, foundry blacking manufacturers, of Penistone, was married on June 30 to Miss F. A. Gadie, younger daughter of Sir Anthony Gadie, a former Lord Mayor of Bradford.

MRS. ETHEL RAWDEN, the daughter of Mr. J. J. McClelland, who is so prominent in the conduct of the affairs of the Wales and Monmouth Branch of the Institute of British Foundrymen, has recently gained a Diploma in Economics at the Cardiff University College.

MR. VICTOR STOBIE informs us that Dunston House, South Park Road, Harrogate (given on this page last week as his new home address), is actually the address of branch offices which he has opened in Harrogate. His home address remains as Langholme, South Drive, Harrogate.

MR. JOHN CURRIE, a Past-President of the Scottish Branch of the Institute of British Foundrymen, who has been foundry manager at Carntyne Steel Castings Company, Limited, Renfrew, has been appointed foundry manager at the Hallside works of the Steel Company of Scotland, Limited.

MR. JAMES DUNSMUIR, manager of the engine shop of John Brown & Company, Limited, Clydebank, has retired after 50 years' service with the firm. Mr. Dunsmuir has supervised the construction of engines and turbines for many famous vessels, including H.M.S. "Hood," the "Aquitania," "Lusitania," "Empress of Britain" and the "Queen Mary." The staff of the firm have made a presentation to Mr. Dunsmuir.

Wills

FIRTH, THOMAS, Torquay, an original director of Thomas Firth & Sons, Limited, steel makers, of Sheffield ...	£76,669
CHAMBERS, FREDERICK, for many years a director and works manager of the Stanton Ironworks Company, Limited	£45,196
CORMACK, J. D., Regius Professor of Civil Engineering and Mechanics, Glasgow University, and formerly Professor of Engineering University College, London	£18,078

Obituary

THE DEATH OCCURRED on July 1 of Mr. William Shepherd, who was a member of the firm of William Shepherd & Sons, ironfounders, of Hume Street Foundry, Arbroath. He was 60 years old.

MR. KENNETH A. WOLFE BARRY died on July 1, aged 57 years. The son of Sir John Wolfe Barry, the eminent engineer, who died in 1918, he was a partner in the firm of Sir John Wolfe Barry & Partners.

New Companies

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

Aeroplane & Motor Aluminium Castings, Limited.—Capital, £100 in 4s. shares. Subscriber: F. J. Groombridge, 110, Douglas Avenue, London, E.17.

Furnace Holdings, Limited, 25, Victoria Street, London, S.W.1.—Capital, £100. Iron and brass founders, etc. Directors: R. A. Baring-Gould and R. Morrison-Jones.

Company Reports

Incandescent Heat Company, Limited.—Net profit for 1935, £8,574; deduct debit of £6,569 brought in; to tax, £1,942, leaving credit of £63 carried forward. Meeting, July 9.

Greenwood & Batley, Limited.—Profit for year to March 31, 1936, £37,085; brought in, £19,843; to depreciation, £12,000; preference dividend, £7,028; ordinary dividend of 4½ per cent., £15,678; carried forward, £22,222. Meeting, July 9.

SOFT FLUX (No. 2308) FOR CAST IRON

has a firing temperature of 720°C. to 740°C. and is suitable for any and every colour.

We specialise in the matching of any colour in this enamel and would welcome the opportunity of demonstrating this for you.

CERAMIC COLOURS

with differences—in quality and cost. We specialise in our customers' difficulties! May we advise and help you with yours?

Samples will be sent on application.

N. SINCLAIR & CO., LTD., CLYDE COLOUR & CHEMICAL WORKS,
NILE STREET, BURSLEM, STOKE-ON-TRENT
Phone: HANLEY 84140 Grams: VITRETIN, BURSLEM

WARNER Special PIG IRONS

- Warner C.B.R. and
- Low Carbon Cylinder
(FOR CYLINDERS, ROLLS, ENGINEERING CASTINGS, ETC.)
- Low Carbon Malleable
(FOR MALLEABLE CASTINGS OF ALL DESCRIPTIONS)

Supplied to any specification between limits of 2·00 and 3·50% Carbon and ·50% and 3·50% Silicon

ACTUAL ANALYSIS CERTIFICATES ARE AVAILABLE WITH EACH DELIVERY

● **Typical Cylinder Pig Iron Specification**

TOTAL CARBON	2·70%
SILICON	1·80%
MANGANESE	·90%
SULPHUR	·06%
PHOSPHORUS	·40%

● **Typical Malleable Pig Iron Specification**

TOTAL CARBON	2·60%
SILICON	·75%
MANGANESE	·50%
SULPHUR	·05%
PHOSPHORUS	·06%

WARNER & CO., LTD. MIDDLESBROUGH

GOSSELL & SON, LTD.

110, CANNON STREET, LONDON, E.C.4.

Telephone No.:—MANSION HOUSE 6754. Telegraphic Address:—"GOSSOTTO, LONDON."

Specialities—

PULVERIZED FUEL INSTALLATIONS for METALLURGICAL FURNACES OF ALL TYPES.

FURNACES, MILLS, BUNKERS, FEEDING APPARATUS, BURNERS, Etc., Etc.
DESIGNS SUPPLIED FOR CONVERSION OF EXISTING FURNACES or for NEW INSTALLATIONS.
OVER 400 FURNACES in SUCCESSFUL OPERATION. TRANSPORT OF PULVERIZED FUEL BY ROAD OR RAIL.

BRIDGEWORK, CONSTRUCTIONAL IRONWORK and LOCOMOTIVES, SPECIAL STEEL CASTINGS, ROLLING STOCK.

Raw Material Markets

Conditions in the iron and steel industry are very satisfactory, and works in all areas are well placed for orders, which will keep them fully active for a considerable period. The output of steel during the first half of this year was a record, but in all probability it will have been eclipsed by the end of 1936. The hematite "loyalty" rebate scheme is now in operation and, in short, prices have been advanced by 5s. per ton, which is returnable as a rebate to consumers who buy only from associated producers.

Pig-Iron

MIDDLESBROUGH.—A further increase in the production of pig-iron in the Cleveland area has been made during the past week, and makers are able to dispatch supplies on a larger scale than has been the case for some months past. Existing contracts account for the full production, however, and there is no iron available for export. At the present time makers are reluctant to enter into any new business, their delivery arrears being so large. All new contracts are made at the new minimum figures of 75s. per ton for No. 3 G.M.B. grade, delivered Middlesbrough or Falkirk, 77s. delivered North-East Coast, and 78s. delivered Clydeside.

Few new transactions have been made in East Coast hematite, the makers being fully sold for several months. Arrears in deliveries are considerable, and are also proving a handicap to the placing of new business. A small tonnage of hematite has been exported, but the needs of home consumers are the first consideration. The demand from overseas buyers is heavy. East Coast mixed numbers are quoted at 85s. per ton, delivered Scotland and North-East Coast, 90s. 6d. delivered Sheffield, and 96s. delivered Birmingham. Consumers who subscribe to the "loyalty" agreement receive a rebate of 5s. per ton on the foregoing figures.

LANCASHIRE.—Heavy tonnages of pig-iron are being taken up by Lancashire machine-tool makers, the light-castings trade, general foundries, and heavy electrical works. There has been little new business transacted recently, and now that the prices of Midland qualities of pig-iron have been raised it is expected that users will call for reduced tonnages. Meanwhile, prices are firm, with offers for delivery in the Lancashire price zone on the basis of 83s. per ton for Staffordshire and Derbyshire No. 3, and also for Lancashire iron equal to Derbyshire, 81s. 6d. for Northamptonshire, and 78s. for Derbyshire forge when required for forging purposes only, and 80s. to other consumers. Scottish foundry iron is quoted at about 90s. per ton, delivered in the Manchester district.

MIDLANDS.—Ironfounders in this area have heavy requirements of pig-iron, and it is believed that users will continue to press for large tonnages in spite of the increased quotations. The revised minimum values are 77s. 6d. per ton for Northants No. 3 and 80s. for Derbyshire, Lincolnshire and North Staffordshire No. 3, delivered Birmingham and Black Country stations. Derbyshire iron below 1 per cent. phosphorus is charged at 2s. 6d. per ton in excess of the foregoing prices. Foundry iron is well inquired for, and deliveries amount to a larger tonnage than the current output. Supplies of forge iron are scarce at 5s. per ton below the value of No. 3 foundry quality. The demand for special irons is maintained at the following prices:—Medium-phosphorus iron, 82s. 6d. per ton minimum, up to 90s.; low-phosphorus, 92s. 6d. to 100s.; refined iron, £6 10s. to £7 15s., according to quality, including delivery to local stations and sidings. Hematite iron is heavily sold over the next few months, and makers are unwilling to further their commitments. Prices, which are subject to 5s. rebate and are applicable only for deliveries up to the end of the year, are as follow:—West Coast mixed numbers, £4 17s.; East Coast No. 3, £4 16s.; Welsh mixed numbers, £4 15s. 6d., delivered Birmingham and Black Country stations, with 1s. 6d. per ton extra if delivered into works in 10-ton lots.

SCOTLAND.—Makers of steelworks iron are experiencing a very heavy pressure for supplies, and many users are obliged to utilise Indian iron, owing to the difficulty of obtaining home material. Foundry iron is still quoted at 79s., f.o.t. furnaces, with 2s. 6d. extra for No. 1. Values for No. 3 Cleveland iron are 75s. f.o.t. Falkirk, and 78s. f.o.t. Glasgow, with other English foundry irons at 1s. 3d. per ton less. Business with the light-castings founders has been at a standstill owing to the holidays, but a resumption was made this week with very satisfactory order-books. The steelworks will be closing for holidays in the near future and, meantime, they are working to capacity. Prices of steel-making iron are:—Mixed numbers East Coast, West Coast and Scottish hematite, 85s. 6d., less 5s. rebate; basic, British and Indian, 75s., less 5s. rebate, all delivered steelworks.

Coke

Consumers who have remained out of the foundry-coke market in the hope that prices would be lowered have done so to no avail, and there is no likelihood of any reduction during the summer months, as is usually the custom. Users are requiring substantial supplies, many of them endeavouring to procure tonnages for use next winter. For delivery in Birmingham and district best Durham coke is offered between 41s. 6d. and 43s., and Welsh from 39s. 6d. to 50s. per ton.

Steel

Active trading conditions continue to rule in the steel market, and, although with the turn of the half-year a slight diminution in the volume of trading is noticeable in some departments, this has not been sufficient to influence the general situation, states the official report of the London Iron and Steel Exchange. In the semi-finished steel market, the position has become more stringent, and there seems to be little material offering on the open market. The British producing works are operating at capacity, but many of them are experiencing difficulty in keeping up their deliveries and are unable to accept fresh business. In the finished-steel section of the market, busy conditions rule, and the periods required for delivery show an increasing tendency to lengthen. A few price readjustments have occurred, and the general tone of the market is firm. Although home trade requirements continue to absorb by far the greater part of the production, export trading has improved, and several oversea markets have become more active.

Scrap

Business in heavy steel scrap on the Cleveland market has been affected by the suspension of deliveries from the merchants, because of considerable importations, and the price is nominal at 57s. 6d. Machinery metal is eagerly taken up at 67s. 6d. per ton delivered works, but supplies are not easy to procure. Foundry cast-iron scrap has advanced in price to 65s. The fact that merchants are reluctant to sell at the current prices is restricting business on the Midlands market, where there is a good demand for all qualities. Heavy steel in furnace sizes is at 52s. 6d. per ton, while 50s. is offered for mixed heavy iron and steel. Heavy, unsheared wrought iron is at 67s. 6d., while heavy machinery metal in cupola sizes is at 70s., good heavy at 67s. 6d. and clean light at 52s. 6d. to 55s. Short, heavy steel, suitable for use in the foundries, is easier at 67s. 6d. per ton, delivered works. Deliveries of scrap in the Scottish area were unsatisfactory during the month of June, and, owing to holiday interruptions, July deliveries will be on a low scale. Heavy steel scrap remains at 57s. 6d. per ton, while basic, or heavy iron and steel scrap mixed, is 5s. less. Wrought-iron piling scrap is quoted around 69s. to 70s., with special quality charged at a few shillings more. Heavy machinery cast-iron scrap is a trifle easier at 68s. 6d. to 70s., for pieces not exceeding 1 cwt., while heavy ordinary cast iron, to the same specification, is around 65s. per ton, delivered f.o.t. consumers' works.

Metals

Copper.—Demand in this country remains on a very satisfactory scale and consumption prospects for the remainder of the year are excellent. Activity on the Continent has been fair, but the international situation is such that business is restricted. Most consumers in the United States are well covered over the next month or two and consequently little new buying has been transacted. Quiet conditions prevail on the German copper market, and although the electrical and motor industries are heavy consumers, the smelters and rolling mills are experiencing a dull time. The German electrical industry is responsible for 50 per cent. of the total consumption. The building industry in Germany is also taking large supplies.

Daily market prices:—

Cash.—Thursday, £36 11s. 3d. to £36 12s. 6d.; Friday, £36 13s. 9d. to £36 15s.; Monday, £36 16s. 3d. to £36 17s. 6d.; Tuesday, £36 16s. 3d. to £36 17s. 6d.; Wednesday, £36 12s. 6d. to £36 13s. 9d.

Three Months.—Thursday, £36 17s. 6d. to £36 18s. 9d.; Friday, £37 to £37 1s. 3d.; Monday, £37 2s. 6d. to £37 3s. 9d.; Tuesday, £37 1s. 3d. to £37 2s. 6d.; Wednesday, £36 18s. 9d. to £37.

Tin.—The South Wales tinplate industry continues to account for a large proportion of the demand for tin in this country, which, however, does not amount to a very substantial tonnage. In the United States industrial demand is only moderate and Continental business also is in a state of comparative quietude. The International Tin Committee met in London on Monday to consider the position regarding the Bolivian under-exports. The Bolivian delegation explained that they were prepared to surrender their right to produce all their under-exports outstanding at the end of May, 1936. The committee agreed to recommend to the signatory Governments that Malaya, the Netherlands East Indies, and Nigeria should produce at the rate of 90 per cent. of their standard tonnages for the current quarter. Seventy-five per cent. of this production is attributable to the international quota and 15 per cent. to arrears surrendered by Bolivia. According to Mr. W. H. Gartsen (Henry Rogers, Sons & Company) the total visible supply at the end of June was 13,348 tons, as compared with 15,048 tons at the end of May. The carry-over in the Straits Settlement was 1,673 tons at the end of June (1,936 tons May), and at the Arnhem (Holland) smelter 515 tons (477 tons May).

Metal Exchange quotations were as follow:—

Cash.—Thursday, £175 15s. to £176 5s.; Friday, £175 to £175 10s.; Monday, £180 to £181; Tuesday, £182 10s. to £183 10s.; Wednesday, £188 15s. to £189 5s.

Three Months.—Thursday, £173 to £173 5s.; Friday, £172 5s. to £172 10s.; Monday, £177 10s. to £178; Tuesday, £179 to £180; Wednesday, £183 5s. to £183 10s.

Spelter.—Conditions with the consuming industries in this country remain satisfactory, with the exception of the galvanisers. Large tonnages have been taken up by the brass, zinc oxide and die-casting concerns, while the electrical, general engineering and building trades are also well employed and thus have heavy requirements of spelter. Buying in the United States has involved some large tonnages and the market, although not fully active, is sound.

Official quotations were as follow:—

Ordinary.—Thursday, £13 7s. 6d.; Friday, £13 8s. 9d.; Monday, £13 10s.; Tuesday, £13 7s. 6d.; Wednesday, £13 3s. 9d.

Lead.—Consumption is reported to be on a good scale in this country and buying has involved considerable tonnages. The position on the Continent has improved. Lead users in the United States have only small stocks and, although little evidence has so far been forthcoming, it is expected that buying interest will increase during the next week or two.

Day-to-day quotations:—

Soft Foreign (Prompt).—Thursday, £15 6s. 3d.; Friday, £15 6s. 3d.; Monday, £15 8s. 9d.; Tuesday, £15 7s. 6d.; Wednesday, £15 7s. 6d.

Notes from the Branches

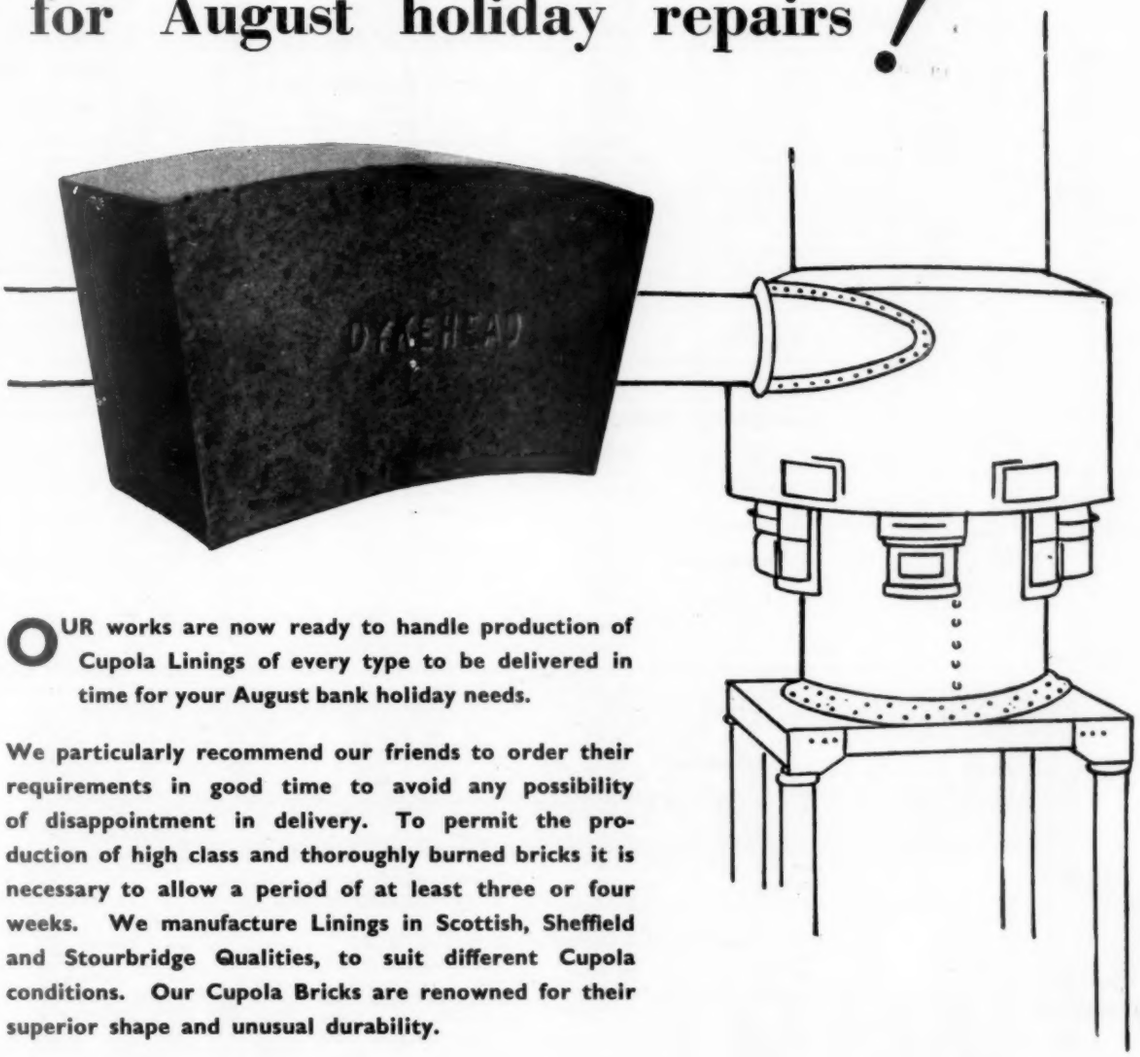
Birmingham.—On Wednesday afternoon of last week a party of forty-five members paid a visit to the Austin Motor Works at Northfield, Birmingham. Members inspected the assembly lines, heat-treatment and forging plants, but concentrated on the foundry department, where they were received by Mr. G. W. Brown (foundry manager), who is President of the Branch, and by Mr. J. J. Sheehan (member of Council).

Considerable interest was shown in the two balanced-blast cupolas, each capable of giving 10 tons per hour and enabling accurate carbon control to be obtained. Instruments are provided for the measurement of air pressure and the weight of air entering the cupola irrespective of weather conditions. This instance is typical of the Austin Motor Works, the most striking feature of which is the attention paid to detail in all aspects of the work.

NOW is the time to order

CUPOLA LININGS

for August holiday repairs!



OUR works are now ready to handle production of Cupola Linings of every type to be delivered in time for your August bank holiday needs.

We particularly recommend our friends to order their requirements in good time to avoid any possibility of disappointment in delivery. To permit the production of high class and thoroughly burned bricks it is necessary to allow a period of at least three or four weeks. We manufacture Linings in Scottish, Sheffield and Stourbridge Qualities, to suit different Cupola conditions. Our Cupola Bricks are renowned for their superior shape and unusual durability.

Please write, phone or call for further particulars.

GENERAL REFRACTORIES LIMITED

Telephone: *Sheffield* 31113 (*six lines*).

Telegrams: "*Genefax, Sheffield.*"

Genefax House, Sheffield

London Office:
Russell House,
Adelphi, W.C.2.
Telephone: Temple Bar 7361.
Telegrams:
"Genefax, Ra d-London."

Scottish Office:
156, St. Vincent St.,
Glasgow.
Telephone: 5250.
Telegrams:
"Genefax,Glasgow."

South Wales Office:
11, Wind St.,
Swansea.
Telephone: 3680.
Telegrams:
"Genefax, Swansea."

RAW MATERIALS—PRICE LIST

(Wednesday, July 8, 1936)

COPPER

	£ s. d.
Standard cash	36 12 6
Three months	36 18 9
Electrolytic	40 15 0
Tough	39 5 0
Best selected	39 15 0
Sheets	68 0 0
India	50 0 0
Wire bars	41 2 6
Ingot bars	41 5 0
H.C. wire rods	44 15 0
Off. av. cash, June	36 7 2⅜
Do., 3 mths., June	36 13 0¹¹⁄₁₆
Do., Sttlmnt., June	36 6 10⅝
Do., Electro, June	40 11 3
Do., B.S., June	39 19 2
Do., wire bars, June	40 15 4½
Solid drawn tubes	10½d.
Brazed tubes	10½d.
Wire	6¼d.

BRASS

Solid drawn tubes	9½d.
Brazed tubes	11½d.
Rods, drawn	8½d.
Rods, extd. or rlld.	8d.
Sheets to 10 w.g.	5d.
Wire	7½d.
Rolled metal	7½d.
Yellow metal rods	5d.
Do. 4 × 4 Squares	5½d.
Do. 4 × 3 Sheets	5¾d.

TIN

	£ s. d.
Standard cash	188 15 0
Three months	183 5 0
English	188 10 0
Bars	190 5 0
Straits	190 0 0
Australian (nom.)	—
Eastern	184 5 0
Banca	190 0 0
Off. av. cash, June	183 6 10⅞
Do., 3 mths., June	181 1 2½
Do., Sttlmt., June	183 5 8½

SPELTER

	£ s. d.
Ordinary	13 3 9
Remelted	13 5 0
Hard	11 5 0
Electro 99.9	15 7 6
English	14 5 0
India	12 10 0
Zinc dust	19 10 0
Zinc ashes	4 5 0
Off. aver., June	14 0 2½
Aver. spot, June	13 17 11

LEAD

	£ s. d.
Soft foreign ppt.	15 7 6
Empire	16 2 6
English	17 10 0
Off. average, June	15 4 3⅜
Average spot, June	15 3 4½

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

Zinc sheets, English	23 10 0 to 24 0 0
Do., V.M. ex-whse.	23 10 0 to 24 0 0
Rods	26 0 0

ANTIMONY

English	66 10 0 to 67 10 0
Chinese, ex-whse.	51 0 0
Crude, c.i.f.	23 10 0

QUICKSILVER

Quicksilver	11 12 6 to 12 2 0

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—	
25%	8 17 6
45/50%	12 15 0
75%	17 17 6
Ferro-vanadium—	
35/50%	12/8 lb. Va.
Ferro-molybdenum—	
70/75% carbon-free	4/6 lb. Mo.
Ferro-titanium—	
20/25% carbon-free	9d. lb.
Ferro-phosphorus, 20/25%	£21 0 0 to £22 0 0
Ferro-tungsten—	
80/85%	3/- lb.
Tungsten metal powder—	
98/99%	3/3 lb.
Ferro-chrome—	
2/4% car.	33 0 0
4/6% car.	21 10 0
6/8% car.	21 0 0
8/10% car.	21 0 0
Ferro-chrome—	
Max. 2% car.	33 10 0
Max. 1% car.	36 5 0
Max. 0.70% car.	37 5 0
70% carbon-free	9½d. lb.
Nickel—99.5/100%	£200 to £205
"F" nickel shot	£184 0 0
Ferro-cobalt, 98/99%	6/3 to 6/9 lb.
Metallic chromium—	
96/98%	2/5 lb.
Ferro-manganese (net)—	
76/80% loose	£11 5 0 to 11 15 0
76/80% packed	£12 5 0 to 12 15 0
76/80% export	(nom.) £10 5 0
Metallic manganese—	
94/96% carbon-free	1/3 lb.

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	2s. 0d.
Finished bars, 18% tungsten	2s. 9d.

Per lb. net, d/d buyers' works.

Extras—

Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to ⅛ in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£ s. d.	£ s. d.
South Wales—		
Heavy steel	3 3 0	to 3 4 0
Mixed iron and steel	2 18 0	to 3 0 0
Heavy cast iron	2 18 0	to 3 0 0
Good machinery	3 2 0	to 3 5 0
Cleveland—		
Heavy steel	2 17 6	
Steel turnings	2 0 0	
Heavy cast iron	3 5 0	
Heavy machinery	3 7 6	
Midlands—		
Light cast-iron scrap	2 12 6	to 2 15 0
Heavy wrought iron	3 7 6	
Steel turnings	2 0 0	
Scotland—		
Heavy steel	2 17 6	
Ordinary cast iron	3 5 0	
Engineers' turnings	2 2 6	
Cast-iron borings	1 17 6	
Wrot-iron piling	3 9 6	
Heavy machinery	3 8 6	

London—Merchants' buying prices, delivered yard.

Copper (clean)	29 0 0
Brass	19 0 0
Lead (less usual draft)	13 10 0
Tea lead	9 0 0
Zinc	8 0 0
New aluminium cuttings	74 0 0
Braziery copper	27 0 0
Gunmetal	28 0 0
Hollow pewter	130 0 0
Shaped black pewter	100 0 0

PIG-IRON

N.E. Coast (d/d Tees-side area)—	
Foundry No. 1	77/6
,, No. 3	75/-
,, No. 4	74/-
Forge No. 4	74/-
Hematite No. 1	85/6*
Hematite M/Nos.	85/-*
N.W. Coast—	
Hem. M/Nos. d/d Glas.	85/6*
,, d/d Birm.	97/-*
Malleable iron d/d Birm.	125/-
Midlands (d/d Birmingham dist.)—	
Staffs No. 4 forge	77/-
,, No. 3 fdry.	80/-
Northants forge	74/6
,, fdry. No. 3	77/6
,, fdry. No. 1	80/6
Derbyshire forge	77/-
,, fdry. No. 3	80/-
,, fdry. No. 1	83/-
Scotland—	
Foundry, No. 1, f.o.t.	81/6
,, No. 3, f.o.t.	79/-
Cleveland No. 3, Glasgow	78/-
,, ,, Falkirk	75/-
Scottish hem. M/Nos. d/d	85/6*
Sheffield (d/d district)—	
Derby forge	74/6
,, fdry. No. 3	77/6
Lincs forge	74/6
,, fdry. No. 3	77/6
W.C. hematite	91/-*
Lancashire (d/d eq. Man.)—	
Derby fdry. No. 3	83/-
Staffs fdry. No. 3	83/-
Northants fdry. No. 3	81/6
Cleveland fdry. No. 3	83/-
Dalzell, No. 3 (special)	102/6 to 105/-
Glengarnock, No. 3	90/-
Clyde, No. 3	90/-
Monkland, No. 3	90/-
Summerlee, No. 3	90/-
Eglinton, No. 3	90/-
Gartsherrie, No. 3	90/-
Shotts, No. 3	90/-

* Subject to a rebate of 5s. per ton under certain conditions

FINISHED IRON AND STEEL

Usual district deliveries for iron; delivered consumer's station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.)	10 2 6	
Nut and bolt iron	8 10 0	to 9 0 0
Hoops	11 0 0	and up.
Marked bars (Staffs) f.o.t.	12 10 0	
Gas strip	11 0 0	and up.
Bolts and nuts, ¾ in. × 4 in.	15 15 0	and up.
Steel—		
Plates, ship, etc.	9 7 6	to 9 10 0
Boiler plts.	9 17 6	to 10 0 0
Chequer plts.	11 0 0	
Angles	9 0 0	
Tees	10 0 0	
Joists	9 7 6	
Rounds and squares, 3 in. to 5½ in.	10 0 0	
Rounds under 3 in. to ¾ in. (Untested)	9 7 0	
Flats—8 in. wide and over	9 5 0	
,, under 8 in. and over 5 in.	9 10 0	
Rails, heavy	8 5 0	to 8 10 0
Fishplates	12 10 0	
Hoops (Staffs)	10 2 0	
Black sheets, 24g. (4-t. lots)	11 10 0	
Galv. cor. shts. (,,)	13 10 0	
Galv. flat shts. (,,)	14 0 0	
Galv. fencing wire, 8g. plain	15 0 0	
Billets, soft	6 2 6	and up.
Billets, hard	7 2 6	to 7 7 6
Sheet bars	6 0 0	
Tin bars	6 0 0	

PHOSPHOR BRONZE

Per lb. basis

Strip	10½d.
Sheet to 10 w.g.	11½d.
Wire	12½d.
Rods	11½d.
Tubes	14d.
Castings	12½d.

Delivery 3 owt. free.
10% phos. cop. £30 above B.S.
15% phos. cop. £35 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

Per lb.

Ingots for raising	7d. to 1/1
Rolled—	
To 9 in. wide	1/1 to 1/7
To 12 in. wide	1/1½ to 1/7½
To 15 in. wide	1/1½ to 1/7½
To 18 in. wide	1/2 to 1/8
To 21 in. wide	1/2½ to 1/8½
To 25 in. wide	1/3 to 1/9
Ingots for spoons and forks	7d. to 1/3½
Ingots rolled to spoon size	10d. to 1/6½
Wire round—	
to 10g.	1/4½ to 1/11½

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, 1/3½ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	21.31
No. 2 foundry, Valley	19.50
No. 2 foundry, Birm.	15.50
Basic, Valley	19.00
Malleable, Valley	19.50
Grey forge, Valley	19.00
Ferro-mang. 80%, seaboard	75.00
O.-h. rails, h'y, at mill	36.37½
Billets	28.00
Sheet bars	28.00
Wire rods	38.00
	Cents.
Iron bars, Chicago	1.80
Steel bars	1.85
Tank plates	1.80
Beams, etc.	1.80
Skelp, grooved steel	1.80
Steel hoops	2.10
Sheets, black, No. 24	2.40
Sheets, galv., No. 24	3.10
Wire nails	2.10
Plain wire	2.40
Barbed wire, galv.	2.60
Tinplates, 100-lb. box	$5.25

COKE (at ovens)

Welsh foundry	30/- to 31/-
,, furnace	24/6 to 25/-
Durham foundry	25/- to 26/-
,, furnace	22/6
Scotland, foundry	30/-
,, furnace	25/- to 26/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14 per box		18/9
,,	28×20	,,	37/6
,,	20×10	,,	26/9 to 27/-
,,	18⅞×14	,,	19/6
C.W.	20×14	,,	15/6 to 15/9
,,	28×20	,,	33/9 to 34/-
,,	20×10	,,	22/6 to 22/9
,,	18⅞×14	,,	15/3 to 15/9

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£6 0 0 to £7 0 0
Bars-hammered, basis	£16 0 0 to £16 10 0
Bars and nail-rods, rolled, basis	£15 15 0 to £16 0 0
Blooms	£10 0 0 to £12 0 0
Keg steel	£30 0 0 to £31 0 0
Faggot steel	£18 0 0 to £23 0 0
Bars and rods dead soft, st'l	£10 0 0 to £12 0 0

All per English ton, f.o.b. Gothenburg
[Subject to an exchange basis of Kr. 18.16 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£ s. d.		
July	2 ..	36 11 3	No	change
,,	3 ..	36 13 9	inc.	2/6
,,	6 ..	36 16 3	,,	2/6
,,	7 ..	36 16 3	No	change
,,	8 ..	36 12 6	Dec.	3/9

Electrolytic Copper

		£ s. d.		
July	2 ..	40 10 0	No	change
,,	3 ..	40 15 0	inc.	5/-
,,	6 ..	40 15 0	No	change
,,	7 ..	40 15 0	,,	,,
,,	8 ..	40 15 0	,,	,,

Standard Tin (cash)

		£ s. d.			
July	2 ..	175 15 0	dec.	50/-
,,	3 ..	175 0 0	,,	15/-
,,	6 ..	180 0 0	inc.	100/-
,,	7 ..	182 10 0	,,	50/-
,,	8 ..	188 15 0	,,	125/-

Tin (English ingots)

		£ s. d.			
July	2 ..	176 0 0	dec.	50/-
,,	3 ..	175 5 0	,,	15/-
,,	6 ..	180 0 0	inc.	95/-
,,	7 ..	183 0 0	,,	60/-
,,	8 ..	188 10 0	,,	110/*

Spelter (ordinary)

		£ s. d.		
July	2 ..	13 7 6	No	change
,,	3 ..	13 8 9	inc.	1/3
,,	6 ..	13 10 0	,,	1/3
,,	7 ..	13 7 6	dec.	2/6
,,	8 ..	13 3 9	,,	3/9

Spelter (Electro, 99.9 per cent.)

		£ s. d.			
July	2 ..	15 11 3	inc.	6/3
,,	3 ..	15 12 6	,,	1/3
,,	6 ..	15 13 9	,,	1/3
,,	7 ..	15 11 3	dec.	2/6
,,	8 ..	15 7 6	,,	3/9

Lead (soft foreign, prompt)

		£ s. d.		
July	2 ..	15 6 3	inc.	2/6
,,	3 ..	15 6 3	No	change
,,	6 ..	15 8 9	inc.	2/6
,,	7 ..	15 7 6	dec.	1/3
,,	8 ..	15 7 6	No	change

Lead (English)

		£ s. d.		
July	2 ..	17 5 0	No	change
,,	3 ..	17 5 0	,,	,,
,,	6 ..	17 10 0	inc.	5/-
,,	7 ..	17 10 0	No	change
,,	8 ..	17 10 0	,,	,,

AVERAGE MONTHLY PRICES OF CLEVELAND No. 3 PIG-IRON.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
1896	37 3	38 4	38 7	38 1	37 4	37 4	36 11	36 11	37 11	39 2	40 5	40 5	38 3
1897	41 2	40 4	40 5	39 2	39 7	40 9	39 6	40 5	41 7	42 5	41 5	40 4	40 7
1898	40 9	40 8	40 6	40 0	40 7	39 11	40 4	41 11	43 0	44 11	49 1	44 3	42 0
1899	46 10	47 11	47 9	49 10	55 11	62 10	71 6	65 9	67 7	68 8	70 0	66 9	60 5
1900	67 10	68 10	73 10	76 2	74 2	68 6	69 3	71 4	70 9	67 8	63 6	58 6	68 9
1901	48 0	46 6	45 8	45 5	45 10	44 7	44 6	45 3	45 3	45 3	43 6	43 1	45 3
1902	43 11	46 7	46 9	47 11	48 10	49 7	50 9	52 1	53 6	52 9	50 9	47 11	49 3
1903	47 3	48 9	51 10	49 0	46 1	46 2	46 7	46 8	45 7	43 6	42 10	41 11	46 4
1904	42 3	42 7	43 3	44 7	44 0	42 10	42 9	43 3	43 1	43 9	46 1	48 7	43 11
1905	48 11	48 0	49 6	50 1	51 5	45 6	45 9	47 5	48 8	52 11	52 9	53 3	49 8
1906	53 9	50 1	48 1	48 8	50 2	50 3	50 6	53 0	54 6	56 8	58 6	62 4	53 6
1907	60 4	58 6	54 10	56 0	61 1	58 1	57 8	57 8	55 7	54 8	50 8	50 0	56 2
1908	48 5	49 3	51 7	51 10	51 6	51 2	50 0	51 4	52 0	49 8	49 4	48 11	50 8
1909	48 10	48 1	46 9	47 9	48 4	48 9	48 6	50 5	51 3	51 11	51 2	50 7	49 4
1910	51 10	51 3½	51 7½	50 10	49 10	49 2	48 10	49 8½	49 3½	49 7½	49 6½	49 10	50 4
1911	49 11½	49 2½	48 5	46 11	46 4	46 6	46 11½	47 4	47 0	48 7	47 4½	48 1	47 7
1912	50 0	49 5½	51 1½	53 7½	54 4	55 1	57 5½	64 6½	61 7½	66 8½	67 8	68 0	58 5½
1913	66 11½	63 8½	64 8	67 1½	66 3	56 9½	56 3½	55 8	55 4	53 0	50 1	50 4	58 10
1914	50 11	51 5½	51 0½	51 4½	51 6	51 6½	51 5	52 3	51 5	50 1	50 3	53 0	51 4½
1915	55 7	56 6	61 0	66 7	65 2	66 10	65 4	66 0½	65 3	65 11	69 10½	75 7½	65 7
1916	80 2	91 6	87 4½	86 10	82 6	82 6	87 6	87 6	87 6	87 6	87 6	87 6	85 10
1917	87 6	87 6	87 6	92 6	92 6	92 6	92 6	92 6	92 6	92 6	92 6	95 0	92 3
1918	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0	95 0
1919	95 0	95 0	95 0	95 0	152 6	160 0	160 0	160 0	160 0	160 0	160 0	160 0	137 8
1920	175 0	175 0	187 6	200 0	208 0	217 6	217 6	221 0	225 0	225 0	225 0	225 0	209 3
1921	222 6	195 0	150 0	126 0	120 0	120 0	120 0	136 3	127 0	120 0	110 0	100 0	137 4
1922	92 6	90 0	90 0	90 0	90 0	90 0	89 0	87 3	92 6	92 6	92 6	91 3½	90 7½
1923	94 6	108 9	125 6	129 4½	128 5	136 0	128 1½	121 11	97 1½	97 0	100 0	100 0	110 6½
1924	99 10	97 3½	91 9	93 9	91 9	89 10½	87 9	85 0	82 5½	80 2½	81 9	81 9	88 7½
1925	80 4½	78 10½	78 0	78 3	76 0	73 10½	71 7½	69 10½	68 1½	66 7½	66 0	66 10½	72 10½
1926	69 4½	70 0	70 0	70 0	72 6	75 10½	86 7½	90 0	93 10½	117 10	120 0	99 0	86 3
1927	85 0	83 1½	81 0	80 0	73 9	70 0	70 0	68 9	67 6	67 6	66 10½	65 0	73 2½
1928	65 0	65 0	65 6	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	66 0	65 9½
1929	66 0	66 9	67 0	68 1½	69 5	71 10½	72 9	72 6	72 6	72 6	72 6	72 6	70 4½
1930	72 6	72 6	70 0	67 6	67 6	67 6	67 6	64 6	63 6	63 6	63 6	63 6	66 11½
1931	59 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 7
1932	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6	58 6
1933*	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6	62 6
1934*	62 6	65 0	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	66 10½
1935*	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	67 6	69 4½	70 0	67 10½
1936*	70 0	70 0	70 0	70 0	70 0	70 0	—	—	—	—	—	—	—

* Delivered Middlesbrough area. Prior to 1933, prices were f.o.t. furnaces.

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WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.

13, RUMFORD STREET, LIVERPOOL.

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NON-FERROUS METALS

REFRACTORIES — COKE — SAND

FERRO-SILICON—FERRO-CHROME

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ZETLAND ROAD, MIDDLESBROUGH.

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(A remittance should accompany instructions.)

SITUATIONS VACANT AND WANTED

EXPERT Foundry Manager, ferrous and non-ferrous, open to re-engagement; guarantee excellent results.—Apply Box 774, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

EXPERIENCED Foundry Foreman seeks position near London. Twenty years' practical training in ferrous and non-ferrous alloys, floor, bench, machine, chilled stick. Good organiser, tactful, live man.—Box 798, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

ESTIMATOR and Draughtsman for iron-foundry, mainly engaged on high-grade repetition automobile and similar castings. Rapidity and accuracy in weight calculations from blue-prints essential, and competence to design special jigs, gauges, etc. Good scope for advancement for right man. Give full particulars of experience, qualifications, age, and wages required.—Box 780, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

MAN to take charge of small completely mechanised moulding section, being added to foundry, producing repetition grey-iron castings. Must be thoroughly experienced in producing with unskilled labour on machine moulding a wide and varying range of small and medium motor and engineering castings, with plates being frequently changed. Excellent opportunity for a real go-getter, keen on obtaining high production rates with minimum scrap. Bonus paid on results, and every encouragement given. State full details of experience, age, and remuneration expected.—Box 782, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

LONDON foundry employing 90-100 men on general work and extending its sphere, requires keen Managerial Assistant, about 30 years of age, sound technical and practical training, experience of cupola control, machine moulding and latest practice essential. State full details and salary required to Box 796, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

MANAGER wanted for Malleable Foundry in Midlands. Capable organiser and disciplinarian to take complete control of entire foundry. State experience, salary required, and when able to commence duties.—Box 790, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

SALES and Estimating Engineer, thoroughly experienced in electric-furnace industry. Excellent opportunity for first-class man. Give full particulars technical education, experience, age, and salary required. Replies treated in strict confidence.—Box 786, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

WANTED, for foundry in Midlands, mechanical-minded Foundry Superintendent for small repetition malleable castings and grey-iron stove plate work. Must have experience in these two types of castings. Apply stating age, wage, and full details of career.—Box 794, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

SITUATIONS VACANT AND WANTED.—*Contd.*

STEELFOUNDRY Foreman wanted with experience in light and alloy-steel castings, used to modern methods and some technical knowledge. An excellent opportunity with prospects for right man. Write giving age, experience, and salary required, to Box 784, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

AGENCY

ADVERTISER with connection amongst foundries in London, Home Counties, Eastern Counties and South Coast desires represent suppliers of Requisites or other Foundry material. Highest references given.—Box 792, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

PROPERTY

WANTED to rent, small Foundry or Premises suitable for conversion. Building 4/500 sq. yds. (Total works area 2,000 sq. yds.) Electric and water services. Lancashire, Yorkshire or Derbyshire districts.—Box 778, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

MACHINERY

NEW Dwarf Cupola, to melt 10 to 15 cwts. per hr. New Worm-geared Ladles, 5 tons, 25 cwts., 15 cwts. and 10 cwts. capacity. Ungeared Ladles, 15 cwts. and 10 cwts. capacity. Improved Cupola Spark Arresters.—T. DAVIES & SON, West Gorton, Manchester.

Tilghman Sandblast Barrel Plants; barrel sizes—60 in. x 40 in.; 36 in. x 20 in.; 20 in. x 30 in.

Tilghman Sandblast Cabinet Plants; 4 ft. 6 in. and 3 ft. 6 in. square (one for high pressure 70 lbs. per sq. in.); also small Cabinet 30 in. dia.

All complete with Air Compressors, etc.

Gas and Air Mixer by Sharpe & Preston, 2-in. outlet.

Six Osborne Pneumatic Jolt Press Moulding Machines, size 75J.

Three Mumford Yoke Headpress Pneumatic Moulding Machines.

Two Herbert Whizzer Sand Disintegrators.

Two Brealey Type ditto.

Heavy Double-ended Grinding Machines by Rowlands, Luke & Spencer, etc.

Hand Moulding Machines by Adaptable Darling & Sellars, Pridmore, Samuelson, etc.

500 Electric Motors, Dynamos, Rotary Converters, etc.

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'Phone: Broadwell 1359.

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"Pridmore" Pneumatic MOULDING MACHINE; type "EV"; take boxes 3′ 6″ x 2′.

Inclining TUMBLING BARREL (Canning); 22″ dia. barrel x 18″ deep; 50 r.p.m.; 12″ dia. F. & L. pulleys.

Davey-Paxman self-contained "Economic" BOILER; oil-fired; 12′ 6″ long x 6′ 6″ dia.; w.p. 140 lbs. sq. in.; Peabody patent oil burners.

Write for "Albion" Catalogue.

'Grams: "Forward." 'Phone: 23001 (10 lines).

ALBION WORKS, SHEFFIELD.

MISCELLANEOUS

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SOUTHPORT.

'Phone: 287 SLOUGH

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Two Tabor Modern Jolt Squeeze and Pattern Draw Machines for boxes 20″ × 14″; as new. Price £65 each.

One ditto, for 20″ square Boxes. Price £70.

Several reconditioned GRIMES Hand Pattern-draw and Turnover Machines. Price £12 each.

One genuine OSBORN Hand Machine. Price £28.

Several nearly new DENBIGH Jolters. CHEAP!

CUPOLETTE, 30″ dia., NEW. Price £26.

PLEASE SEND US YOUR ENQUIRIES.

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14, AUSTRALIA ROAD, SLOUGH
BUY FROM ME AND SAVE MONEY!

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RICHARDSON'S

Established 1857.

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AND

AIR COMPRESSORS.

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Grams: "SANDBLAST, B'HAM."

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